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International Internal Combustion Engine Congress

THE organisers of the International Combustion Engine Congress Appeal have circulated a letter asking for support for British participation in the International Internal Combustion Engine Congress conference which the permanent committee of the Congress intends to organise at The Hague in May, 1955. The subject of the conference is stated to be "The Possibilities of the Diesel Motor in Railway, Marine and Stationary Applications." With regard to marine and stationary applications, these refer to single engines exceeding 10,000 h.p. or engines of not less than 2500 h.p. to give not less than 10,000 h.p. when geared together. Organisations exist in most countries for furthering national participation in the Congress, and the letter deplores the fact that Great Britain is not so represented, and also points out that some nations have used technical reputation at the Congress to commercial advantage. Continuing, the letter recalls that the first Congress was held in Paris in 1951 and that its success encouraged its French sponsors, the Syndicat des Constructeurs de Moteurs à Combustion Interne to establish a permanent secretariat and a standing committee, the intention being to hold a congress at intervals of four or five years as well as intermediate conferences. A conference was held in Milan in 1953 on "The Use of Heavy Fuels in Diesel Engines of High and Medium Power," and again, as at the 1951 Congress, Britain was not officially represented, although both were attended by a number of British delegates. After mentioning the criticism of the lack of advance publicity, the letter states that many engineers in this country are in favour of participation. However, it is recalled that an attempt to organise British support failed, last year, through lack of financial support, since those asked felt that the cost should be more widely borne and so the current appeal is being made to a wider representative field. The object of the appeal as set forth in the letter, is to ensure that British industry takes part in the congresses and to raise funds. With regard to the latter item the maintenance of a secretariat in Paris is given as about £130 per nation, and the letter goes on to state that each nation made a contribution of £500 to the Paris Congress so that if the scheme is widely supported it is estimated that the cost would be about £40 per annum from each firm. The letter invites those who wish to support the appeal to write to the Organisers, I.C.E. Congress Appeal, c/o Diesel Engine Users Association, 56, Victoria Street, Westminster, London, S.W.1.

British Standards Institution and Codes of Practice

READERS of this journal will doubtless be familiar with the "Codes of Practice" which are reviewed from time to time in these columns. As a result of discussions between the Council for Codes of Practice for Buildings, the Ministry of Works, the professional institutions concerned, and the British Standards Institution, it has now been agreed that a Council for Codes of Practice should be established within the British Standards Institution, to be responsible for all work on codes of practice. It is intended that committees will be set up under the Council covering, initially, civil engineering, building construction and engineering services, mechanical engineering, and electrical engineering. In the discussions which have led to the new agreement, we are informed, special emphasis has been laid on the guiding principle of the British Standards Institution of proceeding by general consent; this principle will apply to the work undertaken by the council. The Council will have, within the British Standards Institution, the status of a divisional council and in the preparation of new codes of practice will consult all the professional and other interests concerned with the projects in question. The new arrangements will take effect from April 1st. It is pointed out that essentially, codes of practice are concerned with setting out tried and proven methods of installation, operation and maintenance of plant, machinery, equipment, &c., as opposed to manufacturing requirements relevant to processes which take place before equipment leaves the manufacturer. Codes are thus distinct from—though very closely related to—the Standard specifications which form a large part of the work of the B.S.I. There has been a considerable body of opinion that the development of codes of practice should be more closely related to the work of the B.S.I., not least because it is often difficult to lay down a precise dividing line between a code which defines how a material should be used and a standard specification for the material itself. The need for integration of the two activities was also emphasised in the report of the Cunliffe Committee which investigated the organisation and constitution of the B.S.I. in 1950. There will in future be a single centre in which all codes of practice work will be co-ordinated.

Resumption of "Comet" Services

ON Monday last the Minister of Transport and Civil Aviation, following the recommendations of the Air Registration Board, approved the resumption of passenger services with the "Comet" airliner. It will be recalled that the decision to ground the "Comet" fleet was stated by B.O.A.C. to have been taken voluntarily following the disaster which overtook a "Comet" aircraft in the air on January 11th. It was hoped that a thorough technical inspection of the whole fleet, together with the evidence offered by the examination at Farnborough of the wreckage of the first "Comet" crash, and that from the present salvage operations at Elba, would reveal the causes of these two disasters. At the present moment no single technical factor has been advanced as the sole cause of each or both accidents. It was announced, however, that about fifty modifications, many of them minor ones, were to be incorporated in each machine and the resumption of services on March 23rd with those aircraft depends on the satisfactory completion of this work. What appear to be the more significant modifications provide for armoured protection for the fuel tanks and fuselage to prevent their penetration in the event of turbine blade or disc failure, reinforced fuel pipes and more adequate venting of the electric batteries. Meanwhile salvage operations continue near Elba and several parts have already been recovered. Admiral Lord Mountbatten, Commander-in-Chief, Mediterranean, who is co-ordinating the operations, has stated that the part those concerned are most anxious to retrieve is the centre section and the engines, which, he added, might take six more weeks even if they were lucky.

Collapse of Clinton Hall Tunnel

A REPORT has now been published, by H.M. Stationery Office, on the collapse of the London Midland Region railway tunnel at Clinton Hall, Swinton, near Manchester, which occurred on April 28, 1953. The roof of the tunnel caved in at a point directly underneath an old brick-lined construction shaft, the contents of which, it is stated, must have fallen in one mass into the space below. The surrounding soil, which was a loose mixture of sand and clay, poured into the hole and formed such a large cavity underneath the foundations that two houses collapsed without warning, and the five occupants were killed. The failure was attributed to an inherent weakness in the construction of the tunnel; construction was carried out in 1850, with considerable difficulty, through loose sand and marl. It seems reasonable to assume, the report states, that when the shaft was finally filled in the longitudinal timbers of the supporting frame were left embedded in the arch ring of brickwork; in the course of 100 years the timbers gradually decayed, so that lines of cleavage were created in the arch ring where it had to carry the full weight (nearly 200 tons) of the column of wet sand in the shaft in addition to the stresses from tunnelling in bad ground. The first signs of defect were noticed on April 13th and prompt steps were taken to protect rail traffic. But none of the staff concerned knew of the existence of the shaft and so they did not appreciate the very dangerous conditions, and although the proposed repair plan was a sound one, it is stated, there was delay in executing the work, due to various difficulties. The report states that the loss of tunnel records (through war and fire damage) contributed materially to the accident, and asserts that maintenance staff should know of the existence of old shafts and other features which may cause weakness, and tunnel records should be reviewed for this purpose. Furthermore, it is said, the positions of disused shafts should be marked in the tunnels themselves. Considerable investigation was undertaken to trace the other disused shafts of the tunnel, and the question of permanent closure is still under consideration.

Righting of the "Empress of Canada"

DURING the last week of January of last year, following an outbreak of a serious fire, the "Empress of Canada" capsized and sank in the Gladstone Dock at Liverpool. In March of that year it was announced that salvage by a parbuckling operation would be attempted, and since then preparations have gone forward to culminate, almost twelve months later, in the righting of the ship on Saturday, March 6th. During the long period of preparation internal bulkheads were built in the least damaged parts of the ship, to give additional subdivision, and provide internal buoyancy to aid the lifting force. On the starboard side sixteen tripods, each some 25ft in height and capable of taking a pull of 120 tons, were erected and suitable local stiffening added to the hull structure. From each of the tripods a 9in steel wire having a breaking load of 267 tons was stretched across the dock to pass through sixfold purchases to individual winches mounted upon anchorage blocks which consist of about 4000 tons of reinforced concrete associated with sheet steel piling. To assist in the righting movement eleven steel pontoons, 35ft in length by 14ft in diameter, were attached to the port side of the ship to give, when blown out by compressed air, positive lift of 80 tons each. To augment the up thrust on the port side six pontoons were attached to the starboard side to provide a total down thrust of 600 tons. Steam for the reeving of the wire ropes was provided by Lewis mobile boilers and these, together with six hopper barges belonging to the Mersey Docks and Harbour Board, supplied the steam to the winches during the actual operation. Captain W. R. Colbeck, the marine superintendent and water bailiff of the Mersey Docks and Harbour Board, was in charge of the operation and shortly before high tide on Saturday gave the order to blow out the pontoons to lower the level of water in the ship and to pull on the wire cables. Everything went according to plan and the liner was slowly righted and now rests on the dock bottom. During the next few weeks the necessary work will be carried out to refloat the ship in readiness for towing to the ship-breakers. It is estimated that the scrap value of the ship is about £50,000 and that the cost of salvage will amount to approximately £375,000.

Nuclear Reactors and Power Production

By SIR CHRISTOPHER HINTON, M.A.*

No. II—(*Concluded from page 360, March 5th*)

This "James Clayton" Lecture, presented before the Institution of Mechanical Engineers on Friday, February 26th, deals with the design and construction of nuclear reactors, and particularly of types suitable for the generation of power. A detailed description is given of the British Experimental Pile (BEPO) at Harwell. There follows an account of some of the engineering and construction problems met in the erection of the Windscale piles, and the solutions achieved. The problems involved in designing power-producing reactors are discussed. The possible reactors may be divided into two groups: those which use "thermal" neutrons and are similar in principle to BEPO, and those which use "intermediate" or "fast" neutrons and have a much smaller core size. Within each group are alternatives provided by differences in fuel, moderator, and coolant. A number of these are reviewed, and prospects for the large-scale development of nuclear power are discussed as the following abstracts indicate.

Special Problems in Designing a Reactor for Power Generation

Limitations of Temperature.—We have already seen that the BEPO reactor was designed for experimental work and that the Windscale piles were designed for the production of plutonium. Let us now turn our attention to the special problems which face us when we attempt to design a reactor for use in generating electrical power.

Unfortunately, there is no known way of converting nuclear energy into power without going through a heat cycle. It follows therefore that in designing a reactor for production of industrial power, we must release our heat at the highest possible temperature. There is no nuclear-physical reason why the fission process should not be operated at a very high temperature indeed, but there are plenty of engineering and metallurgical considerations which restrain us from any such attempt at the present time. At the present stage it is more important to be successful than to be clever for our first power generating nuclear reactors, therefore we should content ourselves with securing reliable operation at modest temperatures. It cannot be overemphasised that, whereas the dimensions of the core of a nuclear reactor are determined primarily by nuclear physical considerations, the permissible rate of heat release is entirely a question of the engineering design of the cooling system and of the choice of materials.

Natural uranium contains only a small proportion of the fissile element U235; when it is used in a reactor most neutrons from a U235 fission would be captured by the U238 atoms and a chain reaction would be impossible. This difficulty is overcome in a "thermal reactor" by arranging the uranium as a lattice within a moderator, which slows down the neutrons to the so-called "thermal velocities." Neutrons travelling at thermal velocities are less likely to be absorbed in an atom of U238 and more likely to cause fission in atoms of U235. These fissions release additional neutrons and allow the chain reaction to continue. Because of the need for a moderator and because of the relatively large quantity of natural uranium required to give a critical assembly, natural uranium reactors tend to be large in size. However, the use of enriched uranium—that is, uranium which has been subjected to a physical process to increase the percentage of fissionable U235 which it contains—introduces an additional degree of freedom into reactor design. The fact that the fissile U235 is less diluted with U238 makes it possible to reduce the total uranium charge, and so the overall dimensions of the reacting core can be reduced. If enrichment is carried far enough the way is open for the construction of reactors of a different type, in which there is no moderator and in which the fission process is carried on by intermediate or high-energy neutrons. These so-called "fast reactors" could be fuelled either with uranium highly enriched in U235 or by an artificial blend of plutonium and U238. The cost of enriching uranium is high, and to make the best use of this expensive material we must develop engineering and metallurgical techniques which enable us to remove the maximum quantity of heat from a given quantity of fuel—that is, we must achieve high specific ratings on our fuel elements. One can thus visualise a sequence of reactor designs, forming an ascending scale of enrichment and specific thermal rating and a descending scale of core size.

In the case of a graphite-moderated, gas-cooled, thermal reactor using natural uranium, the heat rating in megawatts per ton of uranium will be relatively low (say, around 1MW per ton). Conduction of heat within the fuel elements themselves does not therefore present a serious limitation. With this type of reactor it is the heat transfer from the surface of the fuel elements to the gas stream that determines the final power rating. The technical design of the coolant channels and of the extended surfaces of the fuel elements is therefore of great importance if the optimum output is to be achieved with a given limitation on the surface temperature. One cannot improve the heat transfer rates beyond a certain point by increasing the gas velocity, since the pumping power would become prohibitive. Again one cannot improve the heat transfer rates by increasing the amount of the extended surface beyond a certain point, since the canning material acts as an absorber of neutrons and if we increase the quantity which is present we shall have to increase the charge of uranium needed to reach the critical size. The only independent variable which can be increased so as to give a substantial gain in the power rating of the reactor is the surface temperature of the fuel elements. Here, however, one is back to metallurgical limitations which at present limit us to temperatures of the order of 400 deg. Cent. (752 deg. Fah.).

After irradiation, unless we are wastefully to throw away our fuel elements, they must be put through a chemical separation process to remove the fission products. This chemical processing is very expensive and we must therefore extend the periods between chemical processing, that is, increase our periods of irradiation, if we are going to reduce our cost of operation.

The design of a fuel element which can withstand a long period of irradiation is difficult; growth and distortion of the uranium will occur during irradiation and it is necessary for the container to accommodate these changes without bursting and allowing leakage of active fission products from the irradiated metal into the coolant stream. It is also essential that the irradiated cartridges can be removed with certainty, either at the end of the proper period of irradiation or in the event of individual failure, despite any distortion that may have taken place.

Consider next a reactor having a higher heat output per ton of fuel in the reacting core; for instance, a natural uranium reactor with heavy water as the moderator and coolant, or a reactor using slightly enriched uranium as the fuel with ordinary light water as moderator and coolant. In either case we can think of heat releases of a few megawatts per ton of fuel. With these higher heat ratings we begin to run into heat transfer problems connected with the elements themselves. So much heat has to be conducted through the uranium that the temperature at the centre of the metal starts to get undesirably high unless we use thinner fuel elements. The use of pressurised water as the coolant enables the necessary heat transfer rates from the surface of the fuel elements to be achieved, but we may get appreciable thermal stresses in the material of the containers.

If we go a step further and consider an intermediate or fast reactor without any moderator we must face still higher heat ratings. Heat conduction within the uranium and through the walls of the fuel element container are now very important. The uranium will certainly be plastic and may be in a near-molten state in the centre of the core. Gaseous fission products formed within the metal may produce large internal pressures there, or may diffuse outwards and build up an internal pressure within the can. Large thermal stresses will be set up in the cans, owing to the steep temperature gradients, and the material will almost certainly be taken beyond the elastic range. Minor variations in the dimensions of the fuel elements or in the distribution of coolant velocity may lead to distortion of the fuel elements.

Whatever type of reactor it may be, we have the problem of compatibility of uranium, canning material, coolant, and moderator under appropriate conditions of temperature and irradiation. It is not surprising that the choice of materials is difficult. If any of the materials of construction are slightly soluble in the coolant we may have mass transfer effects to contend with. Irradiation may bring about chemical reactions between the coolant and the materials of the coolant channels or fuel elements. It may, alternatively, alter the rate of reactions which would otherwise occur more slowly. The result of this mass transfer effect may be the removal of material from one part of the coolant circuit and deposition in another.

Summing up, one can say that the limiting factor in reactor design is the performance of the fuel element and that this is likely to be the case for many years to come.

Limitations of Safety.—A nuclear reactor presents a hazard because of the accumulation of highly active fission products within the fuel. Any accident with a reactor, in the way of a fire or uncontrolled supercriticality, which resulted in the release of fission products from the core, could lead to the contamination of a surrounding area. For normal power station operation in the United Kingdom, therefore, it is essential

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either to build reactors which are inherently safe as regards fire or supercriticality, or, alternatively, to provide adequate containment of the entire reactor plant so that, whatever accident might occur, there could be no release of fission products sufficient to constitute a danger.

Let us consider the possible causes of an accident to a reactor. In the case of thermal reactors the core contains both moderator and coolant in addition to the fuel element. If the coolant is a more powerful absorber of neutrons than the moderator, any loss of coolant from the core would result in an increase of the reactivity of the pile. This is because the neutrons that have previously been absorbed in the coolant now become available to cause further fission and so increase the activity. Such a reactor, for instance, graphite or heavy-water-moderated piles using ordinary light water as coolant, are inherently dangerous. On the other hand, a graphite moderated pile with air, carbon dioxide, or helium cooling is inherently safe, because loss of coolant will not increase the number of neutrons available to cause further fissions. Similarly, it is possible to design a light or heavy water reactor using the same substances both as moderator and coolant in such a way that no sudden increase of reactivity can occur.

With the more highly rated thermal reactors which can be built when enriched uranium is used, accidents are possible because of the small thermal capacity of the core.

It is probable that such reactors will use liquid metals as coolants ; if for any reason circulation of the coolant ceases, the heat capacity of the core is so small that the temperature would rise so quickly as to cause structural disintegration of the core and vaporisation of the liquid metal, which might then catch fire and cause dispersal of fission products. The result of such an accident can be contained by housing the reactor in a suitable vessel which will stand the calculable pressure which may arise. This has been done by the Americans on their site near Schenectady, where they have housed the reactor in a steel sphere 225ft in diameter.

It would be a mistake to suppose that the probability of an accident need be any higher with a nuclear-reactor power plant than with other more conventional power plants, but the results might be more widespread if attention were not paid to the hazards which have been described.

Alternative Types of Nuclear Reactor for Power Generation

Having discussed in general terms some of the problems of designing nuclear reactors for power generation, it will be of interest to review the principal alternative types of nuclear reactor which one can envisage for this purpose at the present time, this is done in ascending order of specific thermal rating and in descending order of core size. The list is not, of course, exhaustive ; other schemes will undoubtedly emerge as a result of fresh scientific discoveries and of developments in the arts of engineering and metallurgy.

Graphite-Moderated, Gas-Cooled, Natural Uranium Reactor.—This type of reactor would be a natural development from the BEPO and Windscale piles. We should need an active core in the form of a cylinder of approximately 30ft in diameter. We would want to aim at reliable operation with a maximum surface temperature for the fuel elements around 400 deg. Cent. (752 deg. Fah.). In order to extract the heat from the reactor at a reasonably high temperature for use in steam raising it would be necessary to put the gas coolant circuit under pressure, perhaps 100 lb per square inch, and this would involve enclosing the entire core in a steel pressure vessel. Allowing for the thickness of reflector, the pressure vessel would have to be nearly 40ft in diameter. Difficulties arise in supporting the great weight of the graphite core and carrying the load through the pressure vessel on to the main supporting structure or foundations.

A possible arrangement for a reactor of this type is shown diagrammatically in Fig. 11. This indicates a core design with

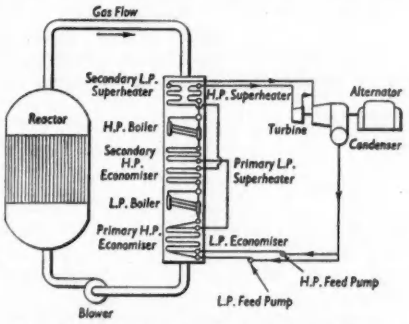


Fig. 11—Diagrammatic Arrangement of Simple Double-Pressure Steam Cycle for Use with a Gas-Cooled Pile

vertical channels. Such an arrangement is convenient so far as the design of the coolant circuit is concerned and also as regards the graphite structure. It leads to difficulty, however, in the method of supporting the weight of the fuel elements. If the reactor is arranged with horizontal channels the latter difficulty disappears, but the design of the graphite structure becomes much more awkward. In either case there is difficulty in arranging a suitable mechanism for charging and discharging the fuel elements. If a separate hole through the shell of the pressure vessel is provided for every channel the design problem is extremely awkward. If, on the other hand, the channels are grouped for charging and discharging the mechanism loses the virtue of simplicity.

In so far as the choice of coolant gas is concerned, the order of preference from the heat transfer and nuclear points of view would be helium, carbon dioxide, nitrogen. If natural uranium is used as the fuel there is only a narrow range of possible core sizes and lattice arrangements. When account is taken of the absorption of neutrons by the material of the cans and by the graphite moderator, it is found that there is only just sufficient reactivity to spare, even when using the best available materials. The design problem would be eased, however, and a much wider range of possible reactor cores could be considered, if slightly enriched uranium were to be used for the fuel charge.

The coolant gas would be circulated round the closed coolant circuit by means of motor-driven blowers, and the outlet temperature of the gas leaving the reactor would be in the neighbourhood of 350 deg. Cent. (662 deg. Fah.). The heat exchangers or boilers could be situated outside the main biological shield surrounding the reactor itself and the turbo-alternator plant could be of conventional design.

The estimated cost of power generation from a reactor of this type built purely for power production would be about a penny a unit for the first prototype plant ; this figure takes no account of any credit from plutonium production. The capital charges form a large part of the estimated cost, but it may be expected that experience in the construction and operation of such plants will enable substantial reductions to be made.

The advantages of the graphite-moderated gas-cooled reactor are its inherent safety and stability and the large thermal capacity of the core. Heat ratings would be quite modest, probably in the range between 1MW and 2MW per ton of uranium, but this means that the capital investment of uranium is large. The main disadvantages of this type of reactor are the large investment of uranium required, the need to use high-purity graphite, and the difficulty of constructing the pressure shell. However, the graphite-moderated gas-cooled reactor is the one for which the greatest amount of knowledge and design experience are available, and the cost of producing power from it appears to compare favourably with the estimates for the cost of power from alternative types of thermal reactor.

Two reactors of this general type are at present being built in Cumberland and will deliver electric power into the B.E.A. grid lines.

Heavy-Water-Moderated Natural Uranium Reactor.—From a physicist's point of view, heavy water is the best moderator for a thermal reactor, since it gives the best neutron economy that is known to be possible. Because of this economy the critical size of the core is smaller and to take advantage of this we must get our heat away from a smaller surface area. The use of a gas coolant is therefore no longer possible and we must use a liquid coolant. Ordinary light water would be an obvious choice were it not for the fact that this would give us an inherently dangerous reactor. It is therefore desirable to choose heavy water for use as coolant as well as moderator.

We are now able to go to ratings in the range between 5MW and 10MW per ton of uranium ; the core will be in the form of a cylinder of perhaps 10ft or 12ft in diameter ; to prevent vaporisation of the coolant within the core it will be necessary to put the whole cooling system under a pressure of, say, 500 lb per square inch. At first sight it would

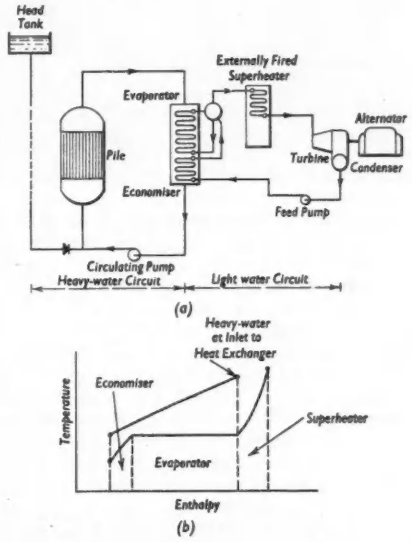


Fig. 12—Superheating in a Separately Fired Superheater

appear that, even with such a pressure, we should not achieve such a good heat circuit for our power plant as with the gas-cooled reactor, since the boiling point of water at 500 lb per square inch is only 242 deg. Cent. (467 deg. Fah.) and our coolant outlet temperature must clearly be less than this. In fact, this comparison is misleading : with water cooling, a high circulation rate can be employed so that the temperature differences

in the boiler are smaller and, in fact, the boiler pressure to be employed in the steam plant would be much the same in the two cases. The main difference is that, whereas with a gas-cooled reactor it is possible to superheat the steam to a reasonable degree by making use of the relatively high temperature of the gas leaving the reactor, this is no longer possible in the case of the water-cooled reactor. If we are not to use saturated steam then the superheating must be done in a separately fired superheater. This arrangement is shown in Fig. 12.

The estimated cost of power generation from a heavy-water-moderated reactor depends very much on the price to be paid for heavy water, since this is the major capital item, but it is probably in the range of 0·75d. to 1·0d. per unit. In many ways the heavy water reactor is an attractive piece of engineering plant. However, it has the great disadvantage of the limited availability of heavy water. A large-scale power programme based on heavy water reactors would have to be preceded by a big capital investment in plants for producing heavy water in quantity and a tiresome period of waiting for production to commence. The possibility of this type of reactor coming to the forefront should, however, not be excluded.

Light-Water-Moderated Reactor Using Enriched Uranium.—As an alternative to the heavy water reactor, it should be possible to employ ordinary light water both as moderator and coolant, provided uranium enriched to perhaps 20 per cent above its normal concentration of U235 can be used as the fuel. We could thus save the cost of heavy water at the price of paying for enriched uranium from a diffusion plant. The general arrangement of the plant would be similar to that shown for the heavy water reactor in Fig. 12. Light water, however, would be used both as moderator and in the primary coolant circuit. We would again be faced with the use of high pressure, perhaps of the order of 1000 lb per square inch. The fuel elements would be generally similar to those required for a heavy water reactor although the exact geometry of the core would be slightly different. The use of light water would give greater freedom in the design of the charging and discharging arrangements. The requirements for the boiler design would again be generally similar to those for heavy water, and it would be desirable to employ a superheater fired by a separate combustion heat source. There are, however, other possibilities for the steam cycle when light water is employed as primary coolant in the reactor. One such scheme employing a flash boiler in place of a heat exchanger is indicated in Fig. 13.

To an engineer there is something particularly attractive about the light water reactor, both in its extreme simplicity and in its avoidance of any extravagant materials of construction. It is perhaps slightly inferior to the heavy water reactor in its economics owing to the use of enriched uranium ; however, it has much the lowest capital cost of any type of nuclear reactor which we can at present envisage and this may be a very important consideration during the next few years.

Intermediate or Fast Reactors.—The next step in this sequence of possible power-producing reactors is to dispense with the moderator altogether and to use a highly enriched fuel. The core of such a reactor, in which the fission process would be carried out by intermediate or fast (as opposed to thermal) neutrons, would contain a fuel having a relatively high proportion of one of the fissile elements or isotopes, U233, U235 or Pu239, together with one of the fertile elements, that is, an element which can absorb neutrons to form a fissile material, such as Th232 or U238.

The absence of moderator results in an active core of very small volume. This volume can, of course, be increased by dilution of the fissile element with a greater quantity of the fertile element or, alternatively, by the addition of some other diluent to the core. Either course of action, however, introduces materials which absorb neutrons and therefore increases the investment of fissile material necessary to give a critical assembly. Since the capital cost of the fissile material in the core is the major item in the economics of this type of reactor, we must therefore face the problem of designing a core of very small size—say, a cylinder 2ft in

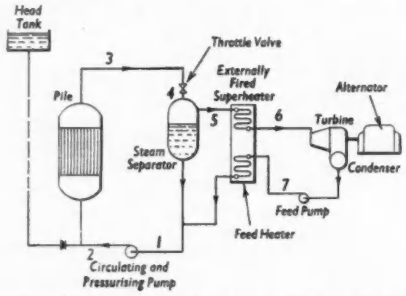


Fig. 13—Steam Cycle for Use with Light Water

diameter and length with a heat rating of perhaps 100MW.

This is a difficult problem, but there are strong reasons for facing it because probably fast reactors can be made to breed more fissile material than they consume, and so, while generating power, they can increase our stock of fissile material. Moreover, if a large number of thermal reactors are to be built and operated for power generation there will be a corresponding production of by-product plutonium, and this could conveniently be used as a fuel in fast reactors.

The whole problem of the fast reactor is centred on the small size of the core. It is not so much the heat transfer from the surface of the fuel elements to the coolant that is the stumbling block, although this is difficult enough, since we may be asking for a heat flux around 3×10^6 B.Th.U. per hour per square foot. High enough values of the heat transfer coefficient could, in fact, be attained by using water as the coolant, provided that the velocity were high enough and the hydraulic diameter of the passages low enough, but other considerations make the use of a liquid metal coolant—sodium or sodium-potassium alloy, for instance—desirable. The real difficulties with these very high heat ratings are the large temperature gradients and thermal stresses occurring in the fuel elements themselves, the difficulty of maintaining reasonably uniform temperature conditions round the surface of the elements, and the distortion of the elements which may take place. The safety problem arising from the small size of a fast reactor core and its small thermal capacity has already been discussed.

In outlining some of the problems of the fast reactor we have implied that the reactor core would be of conventional design in having solid metal fuel elements. Because of our limited knowledge of the physics and engineering of other systems, this is the only form of construction which can be followed at the present time, but one inevitably searches for a better and radically different design. One would like to separate the heat transfer problem from the nuclear physics of the core, and, in fact, to transfer the heat outside the core. One would like to provide for continuous removal of gaseous fission products. One would like an arrangement in which the fuel is already liquid so that the problem of melting of the fuel elements, in the event of a disturbance to the coolant flow, would disappear. Any such scheme which would involve circulating a liquid fuel through the reactor brings up a host of chemical, physical, and metallurgical problems. As regards heat transfer, an evaporative system would be better than a liquid coolant arrangement. A homogeneous reactor core consisting of a solution of the fissile material in some solvent, which was allowed to boil continuously, would have pleasant engineering possibilities. A great deal of work remains to be done and great possibilities are open.

Prospects for the Large-Scale Development of Nuclear Power for Civil and Industrial Use

The estimated cost of electricity generation from a prototype thermal reactor is in the neighbourhood of a penny a unit. This is about 50 per cent higher than the average cost of generation from coal-fired power stations. An artificially low price can, of course, be quoted if a reactor is used as a dual-purpose plant, manufacturing plutonium for defence purposes as its primary product and turning out electrical power as a by-product. It would, however, be unwise to justify a large-scale nuclear power programme on this basis. The proper justification for nuclear power is that, since the cost of production is predominantly the capital charge as opposed to the fuel or operating cost, there are good prospects of bringing down the price. We would certainly hope to reduce the cost of construction of later plants and we would also hope to design for longer life. If we can start at a penny a unit it would seem wise to go ahead and build a few large installations which would give us the necessary operating and engineering experience for future plants capable of generation at lower cost. It should certainly be possible to bring the figure down to about 0·8d. per unit in this way within a few years. In the meantime there is every possibility that the cost of coal, and therefore of electricity generation from coal, will increase. It would not be surprising if nuclear power became fully competitive within another ten years.

There is a further case for nuclear power on the grounds of the actual physical shortage of coal. According to the Ridley Committee, there is at present an unsatisfied demand for coal in the United Kingdom, amounting to some 20,000,000 tons a year ; on a free market, coal might command a higher price. If full account is taken of the present national shortage of coal and of the depletion of our coal reserves, the development of nuclear energy on a large scale as an alternative source of power appears as an urgent national requirement.

All the available evidence suggests that the price of coal will continue to rise steadily in relation to other costs. In addition, the reserves of certain special coals—particularly the best metallurgical coking coals—are running out at an alarming rate. The inevitable tendency will be to treat coal more and more as a valuable chemical substance and less as a raw fuel for burning in its unprocessed form.

Nuclear energy can fit into this picture without in any way disrupting the established fuel and power industries, indeed in the long run it appears to be an essential partner. The proper application of nuclear energy is to generate electrical power on a large scale.

This would have the effect of releasing large quantities of coal which would otherwise be required for the power stations. Some of this coal would be of good quality and suitable for many other uses. Much of it, however, would be of low grade having a high ash content or a large proportion of fines. It is suggested that this could be used in gasification processes, either for preparing town gas or synthesis gases for use in the chemical and liquid fuel industries.

The development of nuclear energy might proceed in two stages. Stage (1) would involve building a large number of thermal reactors for installation in power stations. This part of the programme would aim at making up for the present coal shortage, which seems likely to continue at a level of about 20,000,000 tons a year. It would probably take between twenty and thirty years to reach this target. During this time the by-product plutonium would be produced in the thermal reactors, and this would have to be separated and processed for use in the second stage.

Stage (2) would involve the use of reactors employing highly enriched fuel, in particular, the plutonium from the first stage. Whether these reactors would be fast or intermediate, or whether they would be thermal reactors of a type at present unknown to us, cannot safely be predicted. It would, however, be one of the objectives of stage (2) to achieve breeding of fissile material on a commercial scale.

We are, at present, only on the threshold of atomic energy developments ; what we are doing to-day will look as clumsy and costly in a hundred years' time as one of Watt's early steam engines looks to us, but we may well be opening the door to similarly important advances in power plant engineering.

Annual General Meeting of the Chamber of Shipping

AT the seventy-seventh annual general meeting of the Chamber of Shipping of the United Kingdom, which was held in London recently, Mr. J. C. Denholm was elected president in succession to Sir Donald Anderson. Mr. Denholm opened his presidential address by stating that he could not predict fair weather ahead, but only unsettled conditions, and that the long-term outlook had never been more serious. He deplored the fact that there was too much complacency about the future, based upon the gross profits earned, without due thought being given to the share taken by taxation and the low depreciation allowance compared with that necessary for the building of replacement tonnage. Commenting upon the decline in tramp tonnage, Mr. Denholm pointed out that war-built ships made up most of the present fleet and that these were rapidly becoming too inefficient to operate in a competitive market. Present reserves, he maintained, were inadequate to cover a long-term building programme, and the position of the industry would deteriorate with an accompanying adverse effect on the country's economy unless Government policy was drastically changed. The president quoted figures in support of his contention and asked how the gap between original and replacement building costs could be bridged with freights at low level and taxation at high level. If, he continued, permission to transfer profits untaxed to a building reserve had been agreed the fund created would have been of great help, but now the tramp owner could hardly cover depreciation charges so that the falling off in orders need occasion no surprise. He recalled that in two world wars shortage of ships nearly resulted in disaster and he went on to point out that nine countries had a larger percentage of ships under five years of age than Great Britain. The president touched upon the insidious disease of flag discrimination and referred to the dangers of the fifty-fifty clause in carriage of Marshall Aid gifts.

French Locomotive Experiences

By EDWARD H. LIVESAY

No. II—(*Continued from page* 341, *March 5th*)

PART II—TRAIN No. 309, PARIS/LILLE

SOME of the heaviest and fastest trains on the S.N.C.F. run between Paris and Lille, on which these outstanding 4–6–4, four-cylinder compound locomotives designed by Monsieur de Caso are generally employed ; they were described in detail in the preceding article. On the occasion dealt with in this account, No. 232-U1, was rostered to take train No. 309, which leaves the Gare du Nord at 8 a.m.; it was made up of twelve coaches weighing approximately 650 tons gross. While waiting for the engine, I was joined on the platform by mecanicien Duterre and inspecteur Fillon, with both of whom I had ridden from Calais on a Chapelon " Pacific " hauling the " Golden Arrow " a few days previously ; the run was detailed in THE ENGINEER of February 26th. They were in working rig, and evidently were going to act again in the same respective capacities as on the former occasion, which I was glad of, my first association with them having been so pleasant. In fact, at the preliminary conference with Messieurs Bohl and Segaud, of Monsieur Chapelon's staff, I had made a point of asking that our relations might be renewed whenever possible on Nord runs, to which division they belonged, and apparently my request had been given favourable consideration—as, I may say, my requests always were.

I confess that it was with almost a thrill that I watched " U1 " back into the Gare du Nord and couple on to the train. Very extensive footplate travel has not dulled my admiration for a fine locomotive, and certainly " U1 " looked all that was necessary to rouse enthusiasm in even the keenest critic ; Fig. 15 justifies this eulogy, and the fact that the engine was in a condition of spotless cleanliness only added to the pleasure of looking at it. Preliminary study of the design of these very fine " Hudsons " had raised my interest to a high point, so the prospect of travelling on one of them when it was tackling fast and heavy work, during which its powers would be fully exhibited, was something to anticipate with real satisfaction. " U1 " is unique in several respects among the class of eight engines, as not only was it the last of the octette to be built, but it had originally been intended to fit it with a Ljungstrom turbine, only the outbreak of the war preventing this and leading ultimately to completion in its present form. Everything seemed propitious this sunny morning—the weather, fine and hot ; the load, 650 tons ; the fast and exacting schedule ; the route, with some of which, to Longueau, I was already familiar—all of it being interesting ; and the driver, Duterre, decidedly a " top link " man, judging from my previous experience of him, with whom I had established friendly relations already—a driver who could be depended upon to bring out the engine's potentialities to the full. And last, but by no means least, my *fidus Achates*, Fillon, was again to be at hand to help me over linguistic and technical stiles, besides acting as courier and interpreter during the day. Nothing more was needed to ensure a pleasant and fruitful experience with this splendid machine, and the facts that follow show that my expectations were fully realised.

On getting into the cab, it seemed that history was repeating itself. On the " Golden Arrow " Chapelon " Pacific " there had been a second mecanicien—there was another on " U1," Decaen by name, and I wondered why he was there. This engine had seats, unlike the " Pacific," but this did not mean very much to me ; when riding an unfamiliar locomotive I prefer to stand ; one has more freedom of action and generally a better view of what is going on ; further, if I write sitting down I can seldom read the result. And yet another objection—when there are seats the controls are arranged within easy reach of the people sitting in them, so if I pre-empted the one on the right-hand side—as it was suggested I should—it would only have made things awkward for Chauffeur Douillet. Beyond noting the salient fact that " U1 " was mechanically fired—the grate has an area of 56 square feet—there was no time to familiarise myself with much else in the cab before the engine got under way ; the method of starting these " Hudsons " is unusual and worth describing. Unlike the generality of French compounds, the respective h.p. and l.p. cut-offs cannot be worked independently ; they remain at a

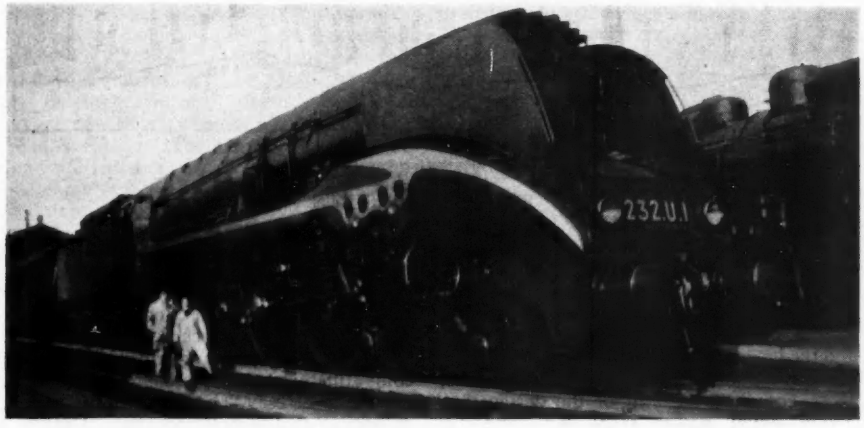


Fig. 15—Hudson Express Locomotive, No. 232-U1, at the Gare du Nord, with M. Leseigneur, Chief of Traction, Nord Division S.N.C.F. (Left) and Inspector Bernard Fillon (Right)

certain definite ratio. As stated last week starting is done on the maximum h.p. cut-off, 75 per cent; at the same time, the obturators open and prevent the passage of exhaust steam from h.p. to l.p. steam chests, directing it to the blast pipes (Kylchap). Simultaneously an automatic double-beat regulator opens, live steam then passing from h.p. to l.p. steam chests; it is admitted to the l.p. cylinders during 90 per cent of the stroke. The engine therefore works as a four-cylinder simple until the h.p. cut-off is reduced to 55 per cent or less, the obturators then coming into reverse action, and the engine beginning to work compound. The regulator is then opened full—it is not so at the start to prevent slipping—and the cut-offs in both pairs of cylinders take up respective degrees for normal running. At the time I was not aware of this unusual starting technique; the details given here are from the *Revue Générale des Chemins de Fer*.

Train No. 309 got away from the Gare du Nord at 8 a.m. O.T., without a trace of slipping; there seldom is any with French engines, in my experience, and I am still not quite sure why, though the fact that the line falls immediately clear of the platform no doubt had some effect on this occasion. Acceleration was rapid, and within a couple of miles the speed had risen to 60 m.p.h. Just past St. Denis, 4½ miles from the Gare du Nord, came the 14-mile 1 in 200 Survilliers bank, (Fig. 16); the climb began at

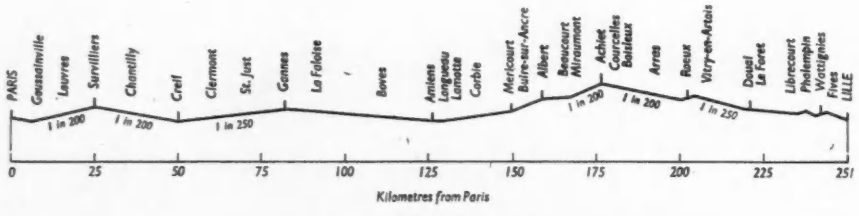


Fig. 16—Profile, Paris/Lille

65 to 70 m.p.h., the speed remaining practically at these figures right to the top. Near the foot of the incline I noted the boiler pressure as 275 lb—the blowing-off figure is 285 lb—the h.p. cylinders were getting steam at 260 lb and the l.p. at 110 lb. These figures, taken "at random" under normal running conditions, show how well the aim of the designer to obtain equal power from h.p. and l.p cylinders has been achieved in practice. The ratio of h.p. to l.p. piston area is 1/2·32; with 260 lb and 110 lb in the respective steam chests the initial piston pressures work out at 62,400 lb and 61,710 lb—close correspondence. It was good work and very interesting to be in the cab watching it being done—650 tons being taken up a gradient of 1 in 200 several miles in length at 60 m.p.h. plus—this was certainly something worth writing about! "U1" was no mastodon deriving its power from mere size, with little perhaps but brute force to differentiate it from other express engines. This was a refined and ultra-advanced machine, carrying not a ton of unnecessary weight, developing power with minimum expenditure of fuel and water, and showing overall efficiency of some 12 per cent, an engine which in beauty of design and completeness of equipment exceeded any locomotive on which I had previously ridden. Little wonder, therefore, that as "U1" rushed up the long acclivity to the Survilliers summit a feeling of complete satisfaction came over me. *This* was the sort of engine an enthusiast dreams of—to wake up and realise it exists only in his imagination. Here it was in reality. Never, I thought, am I likely to find myself in the cab of anything finer than this, and if the reader will look at the sectional elevation and associated matter included in the last article I think he will forgive my enthusiasm, even if he finds it less easy to agree with the dogmatism. Alas, that in Britain, the birthplace of the locomotive, after a century and a half of development, we have nothing approaching "U1." And again, alas, that even in France it will have no successors; in that country, too, the day of the steam locomotive is nearing its end. In any case, the four-cylinder system of compounding is a thing of the past, so far as the country where it has been brought to the highest development is concerned. I was told by informed officials that *if*—if is heavily underlined—it should prove necessary to build any more steam express locomotives for the S.N.C.F., they will be three-cylinder Smith system engines. The de Glehn system of compounding, too, has had its day, and a brilliant one it has been. The explanation of this change-over, of course, lies in the query—if three cylinders can do the work, why use four? And three cylinders can, judging from the striking 4–8–4 that embodies the principle, which will come into a later article.

Returning to "U1," it was not merely a matter of what the engine was doing that delighted me—it was the way it was being done. Riding beautifully, with the light, springy motion that I was to find typical of French locomotives, the splendid machine swept up through Goussainville and Louvres to the summit of the long incline. As it passed over the peak I beckoned to M. Fillon, asking him to tell mecanicien Duterre how delighted I was with the performance, and to congratulate him on his share in it. "But Monsieur Livesay," he said, with a look of surprise, "that is not mecanicien Duterre—that is Monsieur Leseigneur, my Chief! He only drives for love of it, or when important persons are in the train or on the engine—like your late Majesty, or the President of the Republic"—adding an afterthought, "or you!" Well, this was the limit! For the moment, on realising the *gaffe* I had committed, I was too annoyed to feel flattered at finding myself thus numbered among the elect; I was at a loss for words. This overalled, goggled man at the regulator was Monsieur Leseigneur, Chief of Traction, Nord Division, S.N.C.F., (Fig. 15) of whom I had been advised before leaving England, to whom I should have presented my respects at Calais, where he had come on my behalf—or on THE ENGINEER's, rather—and where I had practically ignored him. He had driven the engine to Paris, and had entertained me there in the friendliest way, and I had still failed to recognise him. Now he was doing the same kind of thing again, and once more I had failed to appreciate it, capping the whole series of blunders by calling him out of his name, and publicly demoting him to mecanicien! Very vexed with myself, I begged M. Fillon to explain how the imbroglio had arisen, and to apologise on my behalf. Monsieur Leseigneur laughed heartily, saying it was of no importance; of course, it solved "The Problem of the Second Mecanicien," who had been Duterre, the regular driver, "standing by" while Monsieur Leseigneur drove, just as Decaen was doing at the moment. A simple explanation, which I should probably have discovered for myself at the outset, had I not been so absorbed in the novelty of everything. Incidentally, Decaen also was one of those exceptional mecaniciens, with special training, not a mere run-of-the-mill man.

Down the northern side of the Survilliers ridge, through the Forest of Chantilly, the speed rose close to the 81 m.p.h. limit; this "permission" extended to Clermont, 40 miles from Paris, and normally nearly to Longueau, but from Clermont to Boves it had been temporarily reduced to 75 m.p.h. for trackwork. Another sensible detail was noticed on "U1"—in fact, it is found on all French engines, as I discovered later—the working timetable hung in a little frame right in front of the driver, under his eye at all times. In Britain it is folded up and jammed into some convenient (?) crevice, or stowed in the driver's pocket, from which it is exhumed, crumpled and dirty, when required. I prefer the French plan, which is neat and practical—ours is sloppy. The French are practical people—we are masters of improvisation, which, like many another good thing, can be overdone.

"U1" has a rocking grate, in two sections, front and back, and the in-swinging fire-door mentioned in the last article, but the stoking being mechanical, it was seldom opened, and only for inspection of the fire. The grate was rocked once or twice, but irons were never used. Near the foot of the Survilliers declivity there was a sharp restriction over the Canardiere viaduct, followed by a 60 m.p.h. reduction through Creil. The blowdown was opened every 30 miles for thirty seconds; 75 gallons of water are lost each time; the tender water is treated by chemicals put into the tank. The 23-mile Gannes bank, mostly 1 in 250, begins a little beyond Creil, the speed holding most of the way up at about 65 m.p.h., and St. Just was passed at 8.52; 50 miles in 52 min. The day was baking hot, with the thermometer already over 80 deg., and rising, but the heat was bearable enough in the breezy cab. Grain fields through which we were running, however, showed signs of drought in shortness of straw; considerable patches of burnt-off ground were noticed, evidently caused by engine sparks, and even sleepers burning—one actually in the Gare du Nord, which so shocked me I took it upon myself to put it out—all this gave evidence of the dry weather. But nobody in the cab was inconvenienced seriously, not even fireman Douillet, whose labours, thanks to the "Standard" stoker, were not overstrenuous. This, fitted to "U1," had three jets, as against the usual five in the larger North American fireboxes, but apart from this, the arrangement was much the same, with the stoker engine on the tender. The coal was good, very different from that of the "Golden Arrow"; it was small, uniform in size, and free from dust, and had evidently been screened, the worm acting as conveyor only, not as crusher. The coal being clean, the cab was clean, too; steam was always well up near popping-off point, as it is apt to be with mechanical stoking. There were window wipers, too, on this completely equipped engine, a device which I have always looked upon as a "must" on

an express locomotive—here they were, and, of course, electric light, which apparently is universal on French machines. The cab was as wide as the loading gauge would allow, the front built at an angle, increasing the size of the windows, so the look-ahead was good. The gauge equipment was very complete, included in it being one showing the temperature of the feed water entering the boiler, which should be 75 deg. Cent. (167 deg. Fah.).

Automatic colour-light signals were in use over this section between Gannes and Longueau, and although the gradient was a falling one, the speed was somewhat lower than before owing to local restrictions, and work being done on the track. Boves was passed at 9.16, 1 min early—76 miles in 76 min—and shortly after, at Longueau, we left the Calais line and branched off to the right, running through chalk cuttings towards Arras. Longueau has much to do with the heavy coal traffic from Lens—which will come into a later article—and a large roundhouse is provided there for the freight engines handling it, chiefly 2–10–0 four-cylinder compounds. Once clear of the junction and yard, the speed rose again into the 70s, falling very little up the 1 in 200 gradient to Albert. It was evident we were in the area inseparably associated with the first war, many station names being nostalgic—Albert, Achiet, Thiepval, Beaumont-Hamel, and so on ; Cambrai was only a few miles away to the east. At one point, I believe Thiepval, a great memorial was passed, a further reminder of the " War to end war "—and of its failure to do so. Running free down an easy decline to Arras, I noted the respective h.p. and l.p. cylinder pressures ; they were 65 lb and 28 lb, which shows that, piston areas being as 1/2·32, the two pairs were sharing the work very happily.

The Arras stop was made at 9.52, O.T.; 119 miles in 112 min, 63·8 m.p.h. Two coaches for Dunkerque were dropped here, reducing the load to 550 tons ; the restart was at 9.57, and a fast run followed to Douai, where the arrival was at 10.17, 16 miles in 20 min, which predicates a quick getaway and no time wasted *en route*. The country was level hereabouts ; roads, fields and even the railway were unfenced, resulting in a Manitoba-like landscape, the prevalence of wheat as the principal crop, and the straightness of the highways, adding to the similarity. Apart from this, it was the Lens coal area, with slag piles very prominent. A little hand firing was indulged in nearing Lille, the fuel being placed at the back of the box, so the front of the grate could be cleaned at the shed, and the fire re-spread ; the mechanical stoker would not be so selective.

The Lille arrival was at 10.44, 1 min early ; the 21 miles from Douai had been covered in 23 min, and the whole distance from Paris, 156 miles, in 164 min, inclusive of two stops totalling 9 min, made the average 57 m.p.h.; the running average had been over 60 m.p.h. In assessing this performance it should be borne in mind that the speed had been limited to a maximum of 81 m.p.h., and even that had been permitted only over a comparatively short distance, the greater part having been restricted to 75 m.p.h. or less, with minor local slacks. For three parts of the journey the load had been 650 tons, taken over by no means negligible gradients.

The run had been flawless and the behaviour of the engine equally so ; all three stops had been O.T. or early. I had no means of ascertaining the exact fuel and water consumption, but was told it had probably been about 65 lb and 40 gallons per mile respectively. Better performances have been done in all respects on test runs ; this one was just a regular train running on a definite schedule, and no particular effort was made to achieve anything spectacular, despite the fact that—according to Fillon—an " important person " was in the cab. I was very pleased with everything and everybody ; both the engine and my *compagnons de voyage* had done their best to make the run successful and pleasant—and had succeeded. One more nail had been driven into the coffin of doubts and fears with which I had come freighted to France. If things continue to go as smoothly as they have so far, I thought, there won't be much to worry about.

But in so thinking I was a little premature—the lightning struck immediately on arrival at Lille. At Asnières, early that morning, preparing for the day's excursion and forecasting a hot one—as it happened, correctly—anticipating nothing but locomotive entertainment, I decided to burden myself with no superfluous impedimenta whatever, and to wear the irreducible minimum of clothing—simply overalls, and very filthy ones they were. After all, why not ? The apparel would proclaim the man and the job, and fit in with both environment and company. It worked out beautifully until Lille was reached, whereupon this best laid scheme straightway went all agley. On dismounting from " U1 " and after being introduced to sundry officials, I was staggered to receive an intimation from Fillon that Monsieur Leseigneur and Monsieur Courtin, Superintendent at Lille, would like me to lunch with them. " But look at me ! " I exclaimed. " I can't possibly go to lunch like this—I have no clothes ! " They laughed, and Fillon said reassuringly : " Monsieur Livesay, do not concern yourself—we quite understand—this is France ! " Of course ! I had forgotten this blessed fact for the moment, reacting instinctively as though still in my native land.* So, accepting the invitation, though with inward qualms, I washed—it was the least I could do and unfortunately all—and we proceeded to a very fine restaurant, where for a couple of hours " a feast of reason and a flow of soul," with the usual accessories, were enjoyed. But as Fillon had reminded me, this was France ; nobody showed the least surprise, and my embarrassment faded, to be replaced by a sense of well-being that, at the end of the session, reached a point where I no longer cared very much whether I returned to Paris on a locomotive or an aeroplane. A tour of the shops and sheds followed, during which I was impressed by the obvious signs of order, cleanliness and efficiency to be seen everywhere. A clever briquette-conveyor was shown me, built in the shops ; it handled 40 tons of blocks per day, passing them from manufactory to storage at the rate of one every thirty seconds. Late in the afternoon I mounted a powerful four-cylinder compound 4–8–2 and returned on it to Paris, but it and its striking work had better constitute another article. Ultimately reaching the haven where I would be, Asnières, at midnight, " not fox'd, but plaguey sleepy, having travelled nigh upon eighteen hours," and thinking over the events of the day, I had to agree with Fillon's dictum—that this *was* France, and in addition, that nothing of an equivalent nature could possibly have happened in Britain.

(*To be continued*)

*That my experiences on the S.N.C.F. were so pleasant and fruitful was largely due to the invaluable help and friendliness of the interpreters, without whose care and attention I should have been a lost soul. Two of them—one being inspector Fillon—had achieved an admirable command of English by studying Shakespeare, which sometimes led to amusing situations ; they would use Shakespearean lingo, which, though undoubtedly good English, conveyed nothing whatever to me—it was Elizabethan, certainly, but of the first, not the second era. In resulting attempts to unravel the tangle, they would appeal to me for aid, often to discover that it was not available, they being better acquainted with Shakespeare than I ; we would agree that fifteenth century English had never been intended to cover locomotives. Yet how well the Immortal Bard's phraseology sometimes applied ! As, for instance, Polonius's sage advice to Laertes—I quoted this to Fillon when ruefully apologising for my grubbiness, and he was delighted.

" Costly thy habit as thy purse can buy,
But not expressed in fancy ; rich, not gaudy ;
For the apparel oft proclaims the man,
And they in France of the best rank and station
Are most select and generous chief in that."

That let me out ! French enginemen, too—their overalls seldom gave evidence of more than very infrequent association with a laundry ; the same with mine. Their costume was not expressed in fancy—it was rich (in grime), not gaudy. Their apparel proclaimed the man—French enginemen " are most select and generous chief in that." Surely I, a visitor, when in their company, would do well to emulate them, and not shame them by contrast, by looking as though I had stepped out of a bandbox ? A murrain on such tactlessness !—E. H. L.

Deformed Bar for Reinforced Concrete

THE possibilities of using higher permissible stresses in reinforced concrete design have often been the subject of debate, in discussions at the Institutions and in technical articles, during the past few years. Steel economy, and the high stresses in prestressed concrete practice, have both emphasised the potential economies which would be achieved with higher nominal stresses in reinforced concrete.

This trend of design favours the use of indented or deformed bars, for an increase in the permissible stress in the reinforcing bars means that the strain is increased, and hence a better bond must be achieved to ensure that only " hair " cracks are formed in the concrete of the tensile zones. The use of relatively high stresses in this manner has been investigated in several countries, and we have noted in this journal the progress of such techniques in Sweden and in the United States. Last week, we were invited to a reception held by the Tentor Bar Company, 43, Upper Grosvenor Street, London, W.1, at which the introduction of a deformed bar was announced. The bar is being made in this country under licence from Danish patentees ; before processing it is a hot-rolled round mild steel bar having two parallel longitudinal ribs and transverse diagonal ribs, arranged in a herringbone pattern, and giving the bar constant cross-sectional area. The bar is processed by cold working comprising a longitudinal stretching and a twisting. The stretching virtually eliminates the yield point, giving in effect an increase in strength throughout the bar, and the twisting gives an increase in the strength of the outer fibres.

Some of the properties of the Tentor bar are listed in the table below. The bar is rolled from mild steel according to B.S. 785 (ultimate tensile stress 28–33 tons per square inch), and, according to B.S. 1144 an elongation of 0·5 per cent of the gauge length is accepted as the proof stress. The modulus of elasticity is the same as for mild steel. The makers state that the bars can be bent without difficulty in normal bar bending machinery, and that the steel is not a brittle material, and gives ample evidence of overloading while there is still a reserve of strength. Processing of the bars is carried out by a fully automatic machine in 130ft lengths.

Bars, diameter (inches)	Minimum proof stress, lb/sq in	Ultimate tensile strength, lb/sq in
½, ⅝, ¾, ⅞ and 1	75,000	86,000
1¼, 1½, 1¾ and 2	66,000	76,000

It is pointed out that the present B.S. Code of Practice, CP114 (1948) limits the permissible working stress of these bars to 27,000 lb per square inch, and 20,000 lb per square inch in shear members. Their full advantage will not be obtained, however, unless higher working stresses are employed. A committee of the Institution of Structural Engineers (see *The Structural Engineer*, August, 1953) recommended a maximum working stress of 33,000 lb per square inch for such bars, or 37,000 lb per square inch in slabs. We understand that in some cases local authorities have already indicated that an increase in working stress above the value given in CP114 will be permitted when cold-worked deformed bars are employed.

P. and O. Liner "Arcadia"

No. IV—(*Concluded from page 346, March 5th*)

The liner "Arcadia" recently joined the fleet of the Peninsular and Oriental Steam Navigation Company and sailed on her maiden voyage in that company's service to Australia on February 22nd. A total of 679 first and 735 tourist-class passengers is carried and the ship, which has a length overall of 720ft and a gross tonnage of 29,734, is propelled at a service speed of 22·5 knots. Two sets of double reduction geared turbines develop a total propulsive power of 34,000 s.h.p. and take steam at 500 lb per square inch pressure and 800 deg. Fah.

Steam Plant

To provide the necessary steam there are three two-furnace Foster-Wheeler controlled superheat, oil-fired, water-tube boilers, designed for a steam pressure of 530 lb per square inch gauge and a temperature of 850 deg. Fah. at the superheater outlet. The superheat can be varied down to 600 deg. Fah. when manœuvring and the steam drums are fitted with low-level alarm and oil fuel safety shut-off gear manufactured by Alexander Stephen and Sons, Ltd. The front of one of the boilers is shown in the illustration reproduced on this page. Each one has a total generating surface of 20,355 square feet, which includes the heating surfaces of the boiler, the waterwall and the economiser, the latter having a surface of 6250 square feet. The superheater has a surface of 2525 square feet and each boiler is fitted with a Howden-Ljungstrom air preheater and a Green's economiser having cast iron gilled tubes and an inlet feed water temperature of 280 deg. Fah. When the machinery is developing normal power of 34,000 s.h.p. each boiler has an evaporating rate of 105,000 lb per hour, while the maximum rate is 165,000 lb per hour. The outboard furnace, which has five burners and a combustion chamber volume of 870 cubic feet, has a single-row floor, walls and roof of 2in O.D. tubes, and is separated from the inboard furnace by a bank of seven rows of 1¼in O.D. tubes and four rows of 2in O.D. tubes. The seven-burner inboard furnace has single-row floor and wall tubes of 2in O.D. and a combustion chamber volume of 1240 cubic feet. A bank of five loops of 1¼in O.D. tubes forms the superheater which is shielded by three rows of 2in. O.D. tubes and located to ensure the minimum of steam temperature variation. On the far side of the superheater from the inboard furnace is the main bank of twenty-one rows of 1¼in O.D. tubes.

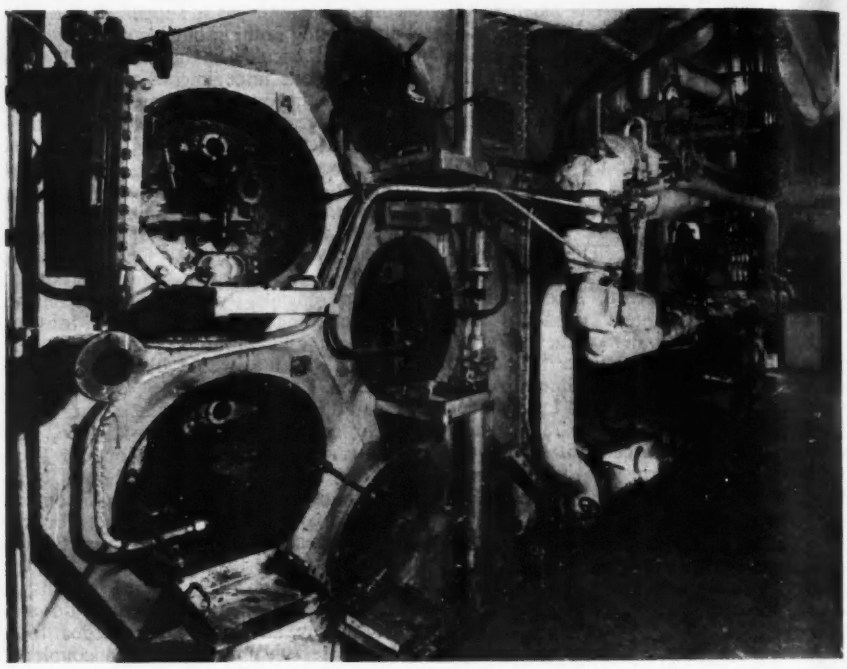
Howden's balanced forced draught system is installed and each boiler has a double inlet forced draught fan, driven by a 151 b.h.p. motor, capable of delivering 60,000 cubic feet of air per minute against a pressure of 10in water gauge, and an induced draught fan, driven by a 400 h.p. motor, rated to deal with 92,000 cubic feet of gas per minute against a pressure drop of 15·5in water gauge. Clyde electrically operated steam soot blowers, controlled from a central board, are fitted to all boilers and air heaters, and there are two Mono CO_2 recorders, supplied by James Gordon and Co., Ltd., which can be switched to any boiler. Cockburn's safety valves and boiler mountings are fitted and British Vacuum Cleaner Industrial Constructions, Ltd., supplied soot-removal plant having a motor-driven, twelve-stage exhauster. "Alfloc" boiler feed water treatment plant is installed and there are two variable-stroke metering pumps, by the Candy Filter Company, Ltd., which can inject at the rate of 6 gallons per hour at 620 lb per square inch. W. Crockatt and Sons, Ltd., supplied its electric salinometers and boiler densometer equipment.

Three Wallsend "Simplex" oil fuel installations are fitted, two working and one standby, and each pump and heater can deal with 13,500 lb per hour at 300 lb per square inch pressure. There is one motor-driven, single-throw lighting-up pump, having a capacity of 1000 lb per hour at 300 lb per square inch and an 18kW heater.

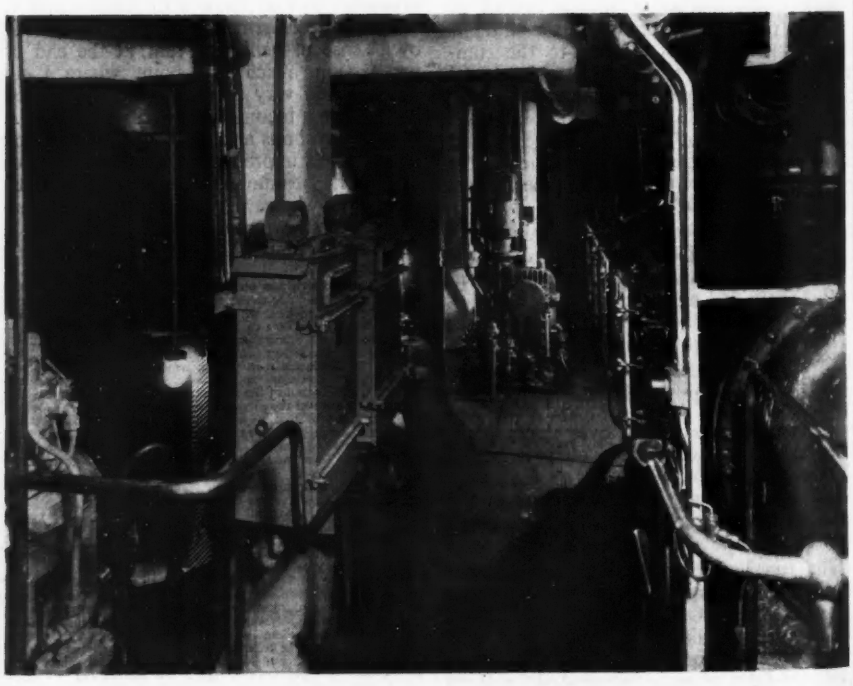
Closed Feed System

Each set of turbines has an underslung two-flow Weir regenerative condenser having a cooling surface of 17,500 square feet and designed to pass 134,000 lb of steam per hour and maintain a vacuum of 28·85in with a sea temperature of 65 deg. Fah., which corresponds to the maximum s.h.p. of 42,500, or 28in at a sea temperature of 86 deg. Fah. at normal service power. The condenser body is of mild steel and the cupro-nickel tubes are of ¾in external diameter by 18 S.W.G. in thickness, and are packed with Crane's flexible metallic packing. For circulating each main condenser there are two Allen pumps, each of 12,000 gallons per hour capacity against a 26ft head, one of which is capable of the duty at service power in cold sea-water, but both operate when the temperature of the sea-water is high. There are also two 8500 gallons per hour auxiliary circulating pumps. A closed feed controller, consisting of a 6in supplementary feed valve and a 4in overflow valve operated by a single float, is fitted. This allows water to be drawn into the condenser from the main feed tank, should the water level in the condenser fall due to a sudden demand for water, and allows water to be discharged to the main feed tank should the water level in the condenser rise.

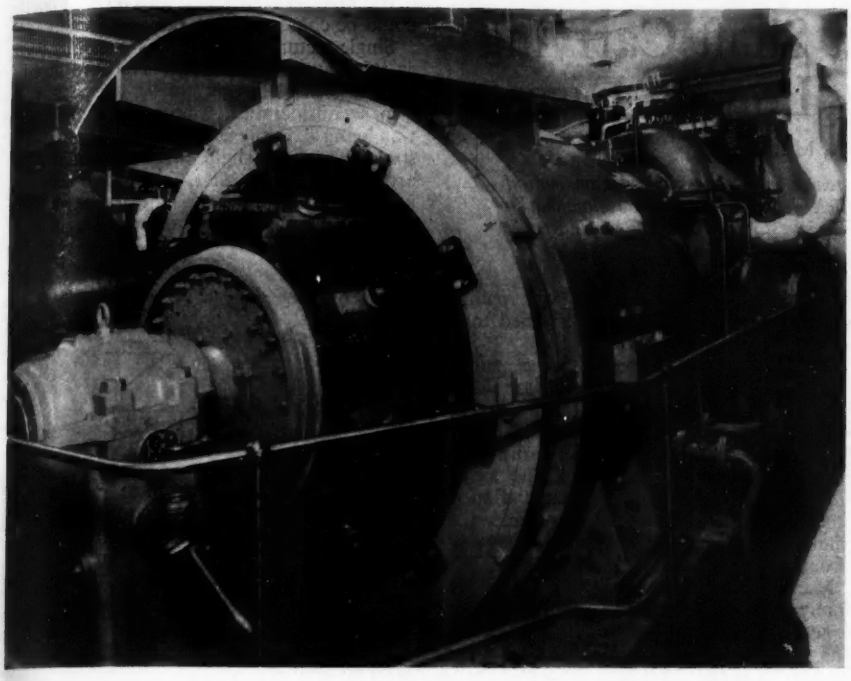
Two centrifugal extraction pumps, each having a maximum capacity of 258,000 lb per hour and a normal service capacity of 198,000 lb per hour against a head of 30 lb per square inch, are fitted to each condenser, and each pump is capable of taking the full load. From each condenser the



View of a Boiler Front



Fresh Water Distillation Plant



1200kW Generator

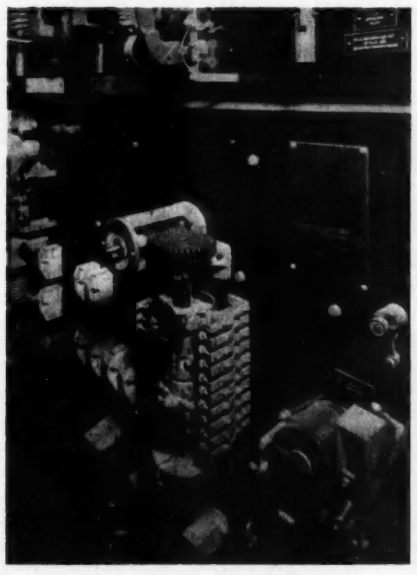
condensate passes through the three-stage main air ejector, which uses 1100 lb of steam per hour at 250 lb per square inch and 750 deg. Fah., and deals with 72 lb of air associated with 120 lb of vapour per hour. From the air injectors the feed from both condensers passes through the drain cooler, which has a tube surface area of 800 square feet, and then through the gland condensers to the suction inlet of the feed pump. There are two working and one standby two-stage, turbine-driven feed pumps, each having a capacity of 350,000 lb per hour against a discharge pressure of 725 lb per square inch, and there is, in addition, one three-stage auxiliary turbo-feed pump of 50,000 lb per hour and one electrically driven nine-stage feed pump of 52,000 lb per hour capacity against a discharge pressure of 725 lb per square inch, for harbour service. Also for use under harbour and low-power conditions, a Weir's de-aerator is fitted, which is capable of handling 66,000 lb of feed per hour under harbour conditions, and 125,000 lb per hour under sea conditions.

On the discharge side of the feed pump the feed passes through the first l.p. heater, which has a tube surface of 950 square feet and is supplied with an air ejector and condenser. It then passes through the second l.p. heater, of 1050 square feet of surface area, to the h.p. feed heater with 770 square feet of surface and at a temperature of 280 deg. Fah., to be discharged through Weir robot feed regulators to the boilers.

Distilling Plant and Auxiliaries

To satisfy the boiler and domestic requirements for fresh water without carrying large quantities of water, a sea-water distilling plant is installed, the economical arrangement of which has been devised by Mr. S. A. Smith, the superintendent engineer of the P. and O. Company. Some of the salt water evaporators can be seen in our illustration reproduced on page 380. With this arrangement the first l.p. feed heater is used as a distiller, for the vapour from the sea-water evaporator, so that most of the heat used in evaporation is recovered in the boiler feed water. Some of the condensate from this heater is pumped to the fresh water evaporator for make-up feed and the remainder is led through a cooler to a domestic water storage tank. The vapour from the fresh water evaporator is condensed in the second l.p. heater and the drain led to the drain cooler. The sea-water evaporators, when working in double effect, can make 550 tons of distilled water per day. The plant, supplied by G. and J. Weir, Ltd., consists of six salt-water evaporators, each of 1050 square feet surface area; one distilled water cooler and primary feed heater having a surface of 900 square feet; one secondary feed heater of 1000 square feet for salt-water evaporators; two feed pumps, two brine pumps and two fresh-water pumps; one fresh-water evaporator of 300 square feet surface and a capacity of 75 tons per day, and two distilling condensers, each capable of dealing with 150 tons of vapour per day. The distilled water is chlorinated on its way to the storage tanks from the cooler and dechlorinated and treated with bicarbonates at a point between the fresh-water pumps and the filters.

Most of the auxiliaries are electrically driven, the motors being supplied mainly by W. H. Allen and Sons, Ltd., and this company, together with Drysdale and Co., Ltd., and G. and J. Weir, Ltd., has provided the majority of the pumps. These include one general service and ballast pump, capable of delivering 250 tons per hour against a 50ft head; two sanitary pumps rated at 220 tons per hour against a head of 120ft; two bilge pumps of 60 tons per hour against 60ft head, and one bath pump delivering 60 tons per hour against a head of 90ft. Included in the Drysdale "Pneupress" system are two pumps of 40 tons per hour capacity against a head of 222ft and an air compressor to deliver 8 cubic feet per minute at 100 lb per square inch. For the sprinkler system there is a pump to deliver 130 tons per hour at 100 lb per square inch and a topping-up pump with a delivery of 120 gallons per hour at a pressure of 150 lb per square inch. Archibald Low and Sons, Ltd., supplied two salt-water and one fresh-water calorifiers, each of 5600 gallons per hour capacity, and a temperature range from 58 deg. to 180 deg. Fah., and an additional fresh-water calorifier of 3 tons per hour, and a temperature range of 50 deg. to 200 deg. Fah., for the galley. The machinery spaces are ventilated by Thermotank axial-flow fans, and, serving the engine are two 25in fans, of 7000 cubic feet per minute capacity; two 40in fans of 17,000 cubic feet per minute capacity, and two 47½in fans rated to deliver 28,000 cubic feet per minute for supply purposes, while there are two 30in exhaust fans of 10,000 cubic feet per minute capacity. For the boiler room there are two 45in supply and four 45in exhaust fans, each of 30,000 cubic feet per minute capacity, while for the cooling screen there are two supply and one exhaust 22½in fans rated at 4000 cubic feet per minute.



Motor-Driven Drum Controller

To meet the electrical demand of the auxiliary machinery, and for heating, lighting, cooking and other ship's services, three 1200kW, 225V d.c. British Thomson-Houston self-contained turbine generators are provided and mounted on a flat at the forward end of the engine-room. Each generating set, one of which we illustrate, has its own condenser, air ejector, closed feed control valve and extraction pump, which has a capacity of 20,000 lb per hour. The turbines drive the generators through single-reduction, double-helical gearing, the reduction being from 5500 r.p.m. at the turbine to 600 r.p.m. at the generator, and take steam at 500 lb per square inch and 850 deg. Fah., with a vacuum of 28½in with the sea temperature at 73 deg. Fah. The field windings of the compound-wound generators, which have an overload capacity of 1500kW for two hours, are totally enclosed and the circulating air is water cooled. In the emergency dynamo room under the forecastle on "B" deck there are two 100kW, 225V d.c. emergency generator sets, each consisting of an Allen generator driven at 600 r.p.m. by a five-cylinder, radiator-cooled Ruston and Hornsby diesel engine. The General Electric Company's plural starter system is installed for the control of a number of motors ranging from 155 h.p. to 8 h.p., many of which are on "essential" busbars. Two common starters are provided, one being standby, mounted on the main switchboard, which, together with the auxiliary and emergency switchboards, were supplied by Whipp and Bourne, Ltd. The switchboard equipment incorporates a motor-driven drum controller, which can be seen in our illustration on this page, and starting resistances.

Award of the Newcomen Medal

At a recent joint meeting in Philadelphia of the Newcomen Society, United States branch, and the Franklin Institute, the Newcomen Medal was awarded to William H. Rowand, vice-president of the Babcock and Wilcox Company, of New York. Among Mr. Rowand's contributions in the field of steam, which led to his nomination for the medal, was his invention in 1936 of the cyclone steam separator. This device effected a thorough separation of steam and water in boiler drums, ensuring circulation of boiler water even at very high pressures. It also facilitated the consistent and uniform delivery of clean, dry steam. He was also active in the subsequent development of higher temperature and higher pressure boilers which this invention made possible. He contributed to the work on the first modern American reheat installation at the Twin Branch power station of the Indiana and Michigan Electric Company, which proved the practicability of the separator and led the way to the introduction of steam pressures of over 2000 lb per square inch and of temperatures exceeding 950 deg. Fah.

Whirling of a Light Shaft Carrying Two Eccentrically Loaded Discs

By E. B. COLE, M.Sc., M.I.Mech.E.

For many years the author has been interested in the stroboscopic demonstration of the whirling of a de Laval rotor. The article describes a recent development in the apparatus used and gives an account of an investigation into the whirling of a light shaft carrying two such rotors.

DUNKERLEY'S theory of the whirling of a de Laval rotor (1884) and that of Jeffcott (1919), which explains matters as a forced vibration, are now well established, and the stroboscopic examination of a model rotor will demonstrate clearly the configuration of the system below, at, and above, the critical whirling speed. Photographic records can easily be taken by use of the "Strobolux" or similar equipment, and a series has been published by the author elsewhere. These theories and experimental verification are eminently satisfactory for a single rotor, but the next steps leading to the consideration of a multiple system are more difficult to visualise, and on many occasions the author has been asked to explain how such a shaft would deflect when

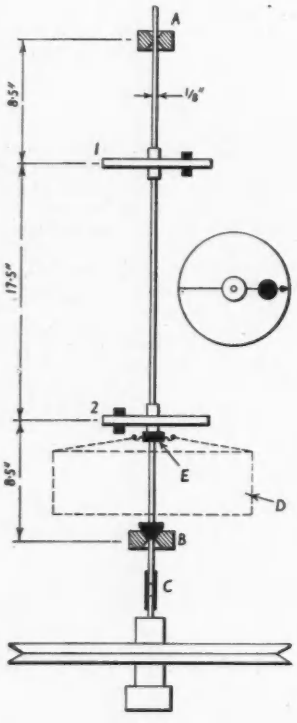


Fig. 1

carrying two or more discs. Thus, the following experimental work was devised to examine the configuration of a symmetrical arrangement of two discs (1), (2), Fig. 1, of equal mass and equal eccentricity of C.G., on a light vertical steel shaft, which was held in knife-edged bearings, *A*, *B*, at its ends.

To support the shaft, a small footstep bearing resting on a spherical seat *B* was employed, while the drive was taken through a flexible coupling *C* from a variable speed electric motor, suitably geared down by a "V"-belt and pulleys.

The discs were made of Perspex, so that the lower one would be visible through the upper in a photographic plan view taken from above, and a radial line through the attached out-of-balance mass was painted on each disc, the C.G. being assumed to lie on this line.

In his original apparatus the author employed a guard-ring to limit the amplitude and the friction of the shaft on this ring enabled a slow approach to the first critical speed to be studied. It was considered, however, that the limitation of the amplitude by this ring over a large range of speed was not satisfactory, and it was decided to eliminate the ring and introduce some form of damping in its place.

Many ideas were tried and the device finally evolved is shown in Fig. 3, the component parts being separated for clarity. The damper element *D* consisted of a perforated cylinder and was attached by a series of cords to hooks on a collar *E*, which surrounded a small ball bearing on the shaft. The damper, when in action, was arranged immediately under the lower disc and dipped into the annular oil bath *F*. This arrangement did not affect the rotation of the shaft in any way and was found to be very effective ; in fact, its steadiness and that of the oil wave when viewed with the stroboscope under whirl conditions was wonderful. (The letter on the circular plate to the right of the picture registered the photographic sequence.) Damping was thus applied to the lower disc only, but this was thought preferable to the use of a guard-ring as it enabled the phase relationships at all speeds to be studied.

As the deflection of the shaft was the important concern of this investigation it was essential to have as long and light a shaft as possible, whilst the mass of the discs compared with that of the shaft should be as large as possible. A limit, however was imposed on these requirements since, to avoid eye strain, it was desirable to keep the lowest running speeds within the persistence of vision. Since the "Strobo-tac" scale of frequency did not go down as low as desired an additional condenser was added and the scale recalibrated.

Certain photographic problems had to be overcome. Since the stroboscope could bring the rotating system apparently to rest, a long time exposure could have been effected with the lens well stopped down, thus enabling both discs to be brought into reasonable focus. However, the difficulty of changing plates quickly, whilst maintaining steady conditions, led the author to replace the ordinary camera first used by a 16mm cine-camera which had a single picture exposure control. The short focal length of the lens gave reasonable focus to both discs at wide apertures, and, with the camera mechanism slowed down to its minimum speed, a succession of well exposed pictures could rapidly be produced.

Although a contactor had been fitted to the shaft, it was preferred to adjust the stroboscope to give a slow creep forward of the shaft, so that cyclical variations could be recorded and pictures, in which the view of the discs was least masked by the upper bearing arm (the rectangular black shadow in the photographs reproduced on the Plates), could be chosen for enlargement.

Single picture exposure was generally used as this gave both a longer exposure due to the shutter not having got up to speed, and also a considerable economy in film, which was being developed in short lengths on the spot. The only slight disadvantage of this arrangement was that, since the camera and stroboscope were not synchronised, occasional frames were unexposed. Ilford

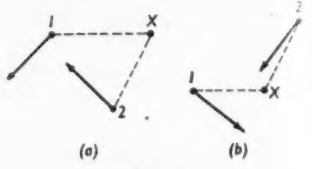


Fig. 2

hypersensitive negative stock, giving fine grain, was found very satisfactory.

The optical axis of the camera was aligned with the axis of the shaft by means of a plumb-line. Each frame of a sequence was examined after having been magnified twenty-five times by projection, and tracings and photographic enlargements were made of all relevant records.

Test Programme

For the investigation concerned, three main tests were run, in which the out-of-balance mass of the lower disc (2) was, respectively, at 0 deg., 90 deg. and 180 deg. behind that of the upper disc.

In the chart, Plate 1, a sequence of the plan view of the discs at various speeds has been plotted direct from the tracings for the three different settings, but an adjustment has been made to the radial distance of disc centre (2) from the axis through the bearings to allow for the smaller image caused by the greater distance from the lens. Rotation was anti-clockwise and the displacement of disc (1) has been plotted horizontally to the left.

A selection of enlargements from the actual film is reproduced in the Plate, and here rotation is in the opposite direction to the drawings (i.e. clockwise) since the tracings were made by projection through the paper. The centre line through the bearings is indicated by a cross and the positions of the disc centres and out-of-balance masses have been indicated by white spots, although in most of the pictures chosen for reproduction they are visible without the need for marking.

When the displacements of the discs are small, not much reliance can be placed on the accuracy of the actual plotted positions, but the general relationship in regard to the curve of bending is clear.

Series (1) : *C.G. of Disc* (2) 0 *Deg. Phase Lag Behind that of Disc* (1).—In this case, as might have been anticipated, the effect up to the first critical whirling speed was similar to that for a single disc with damping. The radial lines through the C.G.s lay more or less in the plane of bending at low speeds with the C.G.s on the outside of the bow of the shaft. As the speed increased these lines appeared to move forward relatively to the plane and became 90 deg. ahead at the critical which occurred at 310 r.p.m. (Plate 1, 1_3.)

On further increase of speed the C.G.s "moved round" towards the inside of the bow but matters were now complicated by the formation of a node between the discs, its establishment being definite at 410 r.p.m. (Plate 1, 1_6). It will be seen that the C.G.s then swung back and became about

WHIRLING OF A LIGHT SHAFT CARRYING TWO ECCENTRICALLY LOADED DISCS

	① R.P.M.	①	② R.P.M.	②	③ R.P.M.	③
1	280	Axis of Bearings / Disc Centres	280		280	
2	300		310		300	
3	310		320		315	
4	325		340		350	
5	385		440 - 475		525	
6	410		500		650	
7	575		650		675	
8	710		675		725	
9	780		700		800	
10	825		750		1,000	

Chart Showing Plan View of Discs at Various Speeds

Stroboscopic Photographs of Whirling of a Light Shaft with Two Eccentric Loads of Varying Phase as Shown in the Accompanying Chart

RADIOACTIVE ISOTOPES IN STEEL FOUNDRY RADIOGRAPHY

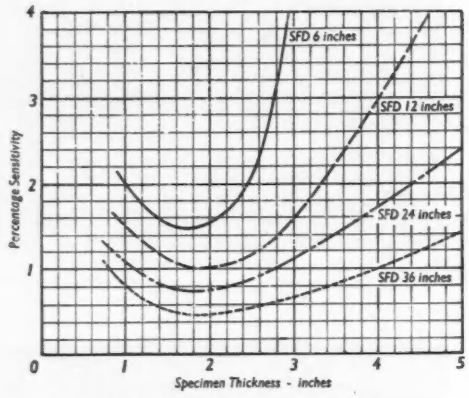


Fig. 1—Sensitivity Curves for Radium

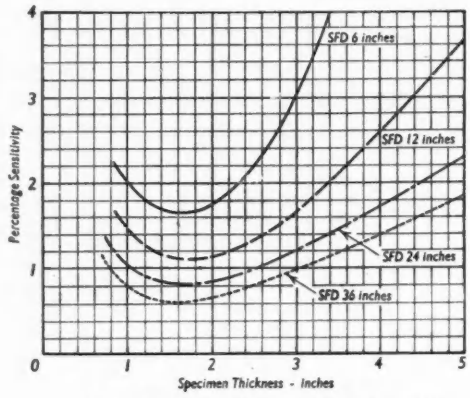


Fig. 2—Sensitivity Curves for Tantalum 182

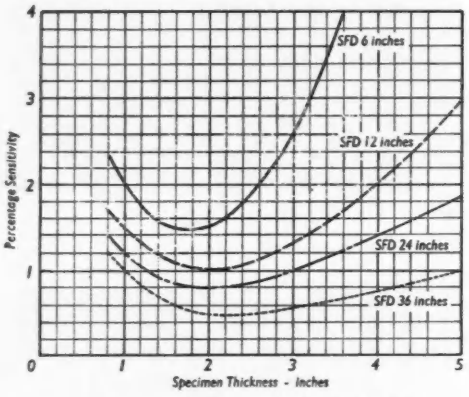


Fig. 3—Sensitivity Curves for Cobalt 60

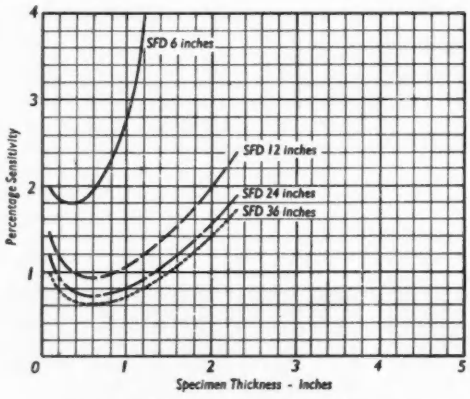


Fig. 4—Sensitivity Curves for Iridium 192

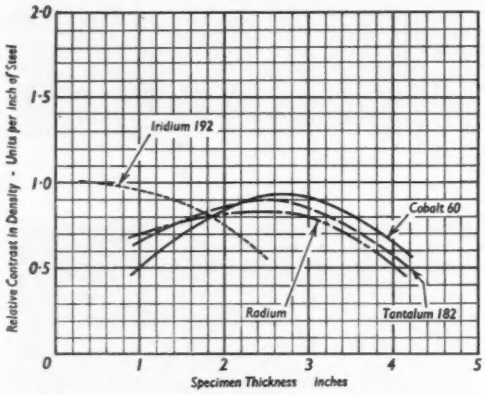


Fig. 5—Relative Contrast as a Function of Specimen Thickness

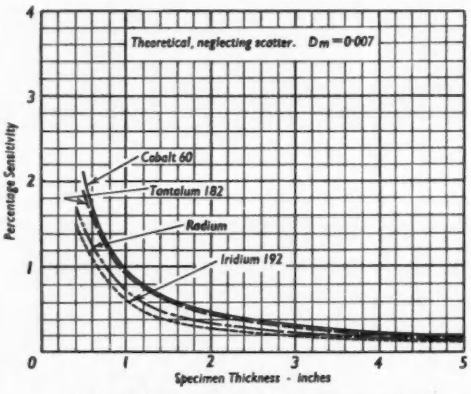


Fig. 6—Contrast Sensitivity (Theoretical) as a Function of Specimen Thickness

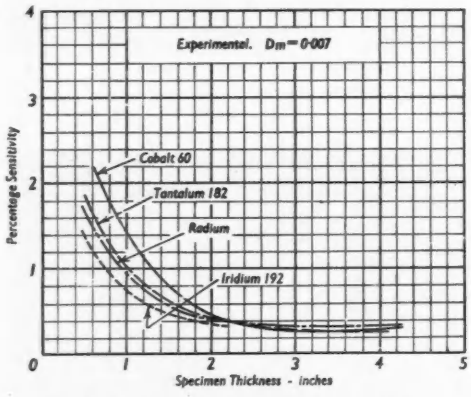


Fig. 7—Contrast Sensitivity (Experimental) as a Function of Specimen Thickness

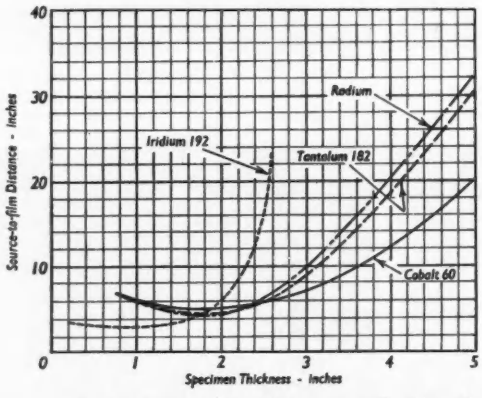
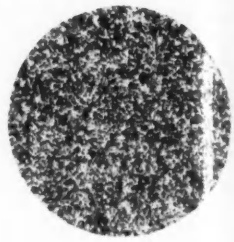
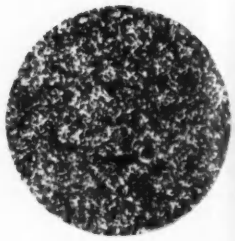


Fig. 8—Source-to-Film Distance as a Function of Specimen Thickness for 2 per Cent Sensitivity



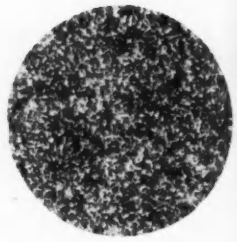
(a)

220kV, X-rays



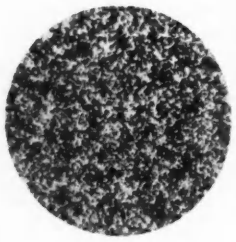
(b)

Iridium 192, gamma rays



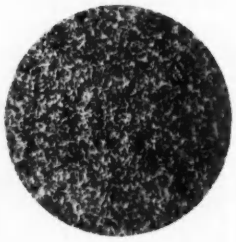
(c)

Radium, gamma rays



(d)

Tantalum 182, gamma rays



(e)

Cobalt 60, gamma rays

Fig. 9—Typical Film Reproductions of Radiographs

90 deg. to the plane of bending at 710 r.p.m. (Plate 1, 1_8), after which a forward movement took place again with increased amplitude of disc (1) up to about 780 r.p.m. (Plate 1, 1_9). Up to this point the motion had been steady and the curve of bending of the shaft had been in one plane, but above this speed the curve of bending no longer lay in one plane, the node being displaced from the axis through the bearings. A marked change in the position of the C.G.s occurred and the motion became very unsteady. A cyclical wandering of the C.G.s now appeared to occur, as if each in turn was trying to swing inside its particular bow. A mean position is shown in the chart, Plate 1, 1_{10}. A similar wandering was noticed in the second series and to determine whether these motions have a definite frequency

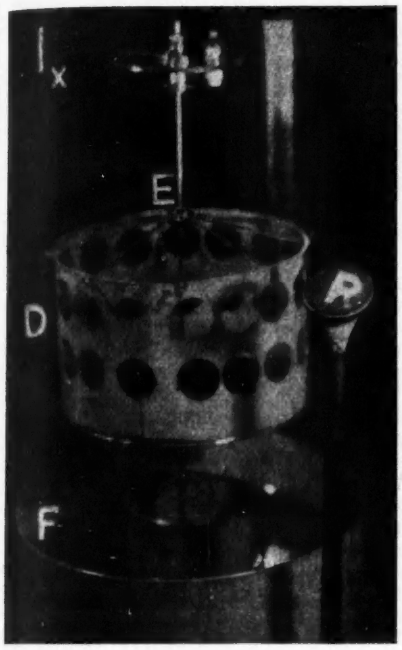


Fig. 3

further experiments would be necessary with the camera running at a uniform speed.

Series (2) : *C.G. of Disc* (2) 90 *Deg. Lag Behind that of Disc* (1).—Here also the first whirl occurred at about 310 r.p.m. and the plane of bending was approximately at right angles to a line bisecting the radial lines through the C.G.s (Plate 1, 2_2). At 340 r.p.m. it will be seen that the C.G.s had moved forward until the plane of bending coincided with this bisector. On further increase of speed a wandering took place as if each C.G. in turn had tried to set itself within the shaft bow (440–475 r.p.m.). At about 500 r.p.m. a node started to form and the C.G.s moved forward in the direction of rotation and took up the position shown (Plate 1, 2_7) at 650 r.p.m. The second whirl took place at about 700 r.p.m. (Plate 1, 2_9.)

Above 750 r.p.m. the motion again became very unsteady and the curve of bending was markedly no longer in one plane, the node being displaced a considerable distance from the axis through the bearings. A cyclical wandering occurred between the limits shown in Fig. 2 (*a*) and (*b*), with varying distance between the disc centres, but the motion became too complicated for single picture examination.

Plate 1, 2_Y, 2_Z, recorded simultaneously at the second critical speed, were taken in some initial trials without damping and are included here as they show clearly, by the large amplitudes attained, that the curve of bending is no longer in one plane. The node was steadied in a split bearing at the end of two flexible arms, which offered no serious constraint to the shaft. Above the speed shown the deflection of the node from the axis through the bearings became so pronounced that this flexible clip had to be held by hand, as also in the motion under review above.

Series (3) : *C.G. of Disc* (2) 180 *Deg. Lag Behind that of Disc* (1).—Due to the centrifugal disturbing forces being in opposition, the amplitudes of the discs at slow speeds were so small that not much reliance could be placed on the actual positions plotted from the enlargements as any irregularities in the straightness of the shaft would no longer be negligible. At about 300 r.p.m. the radial lines through the two C.G.s appeared to be at right angles to the plane of bending with that of disc (2) leading (Plate 1, 3_2), and this was checked by a previous run without damping in which the amplitude was controlled by a guard-ring. The node formed at a very low speed, 315 r.p.m. (Plate 1, 3_3), and at 525 r.p.m. the C.G.s lay in the plane of bending on the outside of their respective shaft bows. From this point the behaviour of each disc on its own length of shaft up to the node was exactly the same as for a single disc, each C.G. moving to a position 90 deg. ahead relative to the plane of bending, the second critical then occurring, and thence to 180 deg. ahead, the motion being quite stable (Plate 1, 3_8 and 3_9). It will be noticed that, probably due to the damping, the C.G.s were 90 deg. ahead at 725 r.p.m., whilst the maximum amplitude was recorded at 675 r.p.m. (Plate 1, 3_7).

General Observations

This particular investigation involved the examination of several thousands of photographs, many check runs having been made. Where prediction from single rotor considerations was possible, the observed configuration in every case was found to agree, and it is clear that the mass distribution affects the configuration and steadiness of running to a marked degree. (The problem of balancing such a flexible system is discussed by Den Hartog in his book *Mechanical Vibrations* and in other text books on the subject.)

Whilst we have not been primarily concerned with the actual values of the whirling speeds, yet it will be observed that the first critical occurred at about 310 r.p.m. and was fairly well defined in each series. The second whirl, however, was not so clearly indicated, but, taking that of series 3 as giving the best indication, 725 r.p.m. would appear reasonable.

Application of Radio-Active Isotopes to Steel Foundry Radiography

By L. WILKINSON

In this survey of the use of radio-active isotopes in steel foundry radiography the author examines the physical principles and practice of radiographic techniques. He shows that the radio-active properties of cobalt 60, *tantalum* 182 *and iridium* 192 *are largely complementary and that they enable thicknesses ranging from a* ½*in to* 5*in of steel to be examined with adequate contrast and sensitivity.*

THE advent of artificially produced radio-active isotopes has provided the radiographer with new sources of radiation which widen the field of gamma ray technique in industrial radiography.

As by-products of the atomic pile, these radio-active sources are obtained by introducing a suitably sized piece of a stable element into the nuclear field within the pile, where, during the subsequent "bombardment" process that takes place in this field, the nuclei of the atoms of the element capture neutrons. An atom which thus acquires an extra neutron in its nucleus becomes unstable, its stability only being regained by the emission of particles and/or radiation from its nucleus. The rate of these atomic disintegrations determines the intensity of radiation available.

Although it has been found that almost all the elements, together with their associated compounds, may be made radio-active, only three have been generally adopted as sources for industrial radiography. They are the unstable isotopes cobalt 60, tantalum 182 and iridium 192, each of which has characteristics which satisfy the general requirements of the steel foundry radiographer. That is, they emit high energy gamma rays for an appreciable period.

In the past, naturally radio-active radium and its gaseous emanation radon have both been most widely used as sources of gamma radiation, and, radiographic results obtained by their use being already well established, an effort has been made to draw a direct comparison by utilising the gamma ray sources of cobalt 60, tantalum 182 and iridium 192, together with a 200 mg radium capsule, in a series of investigations; the latter thus provides a standard. (Radium and radon both emit the same energy gamma rays, these coming mainly from the decay products radium B and radium C in the decay chain, thus the qualitative remarks which apply to radium apply equally well to radon.)

Physical Data

The Intensity of Radiation, or Activity.—The intensity of radiation, or activity, of radio-active materials is dependent on the number of atomic disintegrations taking place per unit time. After neutron irradiation, the initial intensity of the gamma rays emitted by an artificially produced isotope is thus a function of the time the source was kept in the pile, the material and size of the source, and the flux density of the neutron field where the source was placed. The unit of intensity of radiation is the curie, its basis being the fact that this activity is possessed by one gramme of pure elemental radium and is equivalent to $3{\cdot}7\times10^{10}$ disintegrations per second. This gives rise to the term specific activity, the specific activity of pure elemental radium being 1 curie per gramme.

Rate of Decay.—When the isotope is removed from the atomic pile, the intensity falls off exponentially with respect to time: it is said to decay. This is true for all radio-active materials whether of natural origin or artificially produced, and it means that

the rate of atomic disintegration is proportional to the number of radio-active atoms present, or

$$-dI/dt=kI \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where I is the total number of radio-active atoms and k is a constant known as the decay constant.

From (1),

$$dI/I=-kdt \quad . \quad . \quad . \quad . \quad (2)$$

and integrating,

$$\log_e(I_t/I_0)=-kt \quad . \quad . \quad . \quad . \quad (3)$$

where I_0 is the number of atoms at time zero and I_t is the number remaining after time t.

Therefore,

$$I_t=I_0e^{-kt} \quad . \quad . \quad . \quad . \quad (4)$$

An alternative method of indicating radio-active decay is by the use of another constant known as the " half life," this being the time taken for the activity of a radio-active element to decay to half its original value, or

$$I_T/I_0=\tfrac{1}{2}=e^{-kT} \quad . \quad . \quad . \quad . \quad (5)$$

where T is the half life.

Therefore,

$$-kT=\log_e \tfrac{1}{2}=-0{\cdot}693 \quad . \quad . \quad . \quad (6)$$

$$T=0{\cdot}693/k \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Radiation Energy.—The theory is that the origin of gamma rays is due to nuclear transitions between discrete energy levels in the nucleus of an atom (an analogy with X-ray spectra due to extra-nuclear electronic energy levels). This gives rise to one or more discrete gamma energies depending on the nature of the source. The unit of energy used for measuring the energy quanta of gamma photons is the electron volt, eV, which is the gain in kinetic energy by an electron which falls through a potential gradient of 1V :

$$1eV=1{\cdot}6\times10^{-12} \text{ ergs.}$$

According to Planck,

$$E=h\nu \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where E is the energy quantum for a particular radiation, ν is the frequency of vibration, and h is a constant (Planck's constant).

Thus the energy of a given radiation is directly proportional to its frequency of vibration, and, since the rays are electromagnetic in nature,

$$\nu=c/\lambda \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where c is the velocity of light and λ is the wavelength.

Therefore,

$$E=hc/\lambda \quad . \quad . \quad . \quad . \quad (10)$$

that is, the energy is inversely proportional to the wavelength.

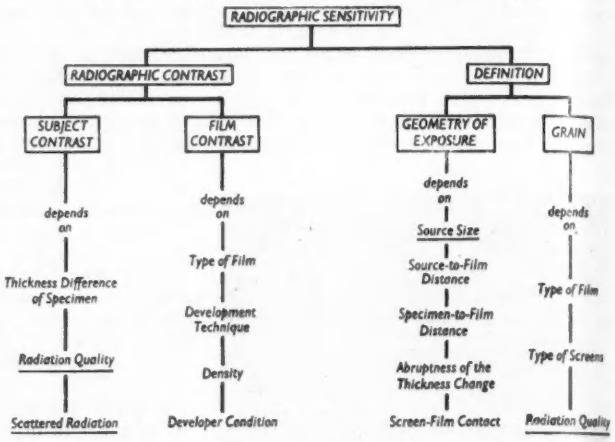
Quantity of Radiation.—The unit of quantity of radiation is the roentgen, and it is defined as that quantity of X or gamma radiation such that the associated corpuscular emission per 0·001293 grammes of air (1 cubic centimetre at N.T.P.), produces in air ions carrying one electrostatic unit of quantity of electricity of either sign.

A rough formula for converting curies to roentgens is $R=6EC$, where R is the number of roentgens at a distance of 1ft from the source, C is the activity in curies and E is the energy in MeV.

Sensitivity and the Discernibility of Defects

The ability of a technique to disclose inhomogeneities in a subject is termed radiographic sensitivity. A quantitative significance may be given to this term by the employment of a standard test strip, or penetrameter, on the source side of the specimen during exposure. This penetrameter strip is made up of small sections, or wires, of known thicknesses, the material of these various sections being the same substantially as the specimen under examination. If the thicknesses have been suitably chosen, scrutiny of the resultant outlines on the radiograph will enable the " penetrameter sensitivity " to be ascertained. This is the smallest thickness change detectable on the film and it is usually quoted as a percentage of the total—that is the subject, thickness. A radiographic technique is normally considered satisfactory if a 2 per cent difference in subject thickness can be detected, although this does not necessarily mean that all defects, or even any defect, of this size will be seen. Due to their orientation and nature it is quite possible that defects appreciably larger than the quoted penetrameter sensitivities may remain unrevealed. The degree of sensitivity attainable is dependent on many factors, but they can be summed under two main headings, " Radiographic Contrast " and " Definition." Table I shows the factors governing sensitivity, and their relationship to contrast and definition.

Table I—*Factors Governing Sensitivity Contrast and Definition*



Radiographic Contrast.—This is the change in density* between different areas of a radiograph and it is dependent on (i) subject contrast—the ratio of radiation intensities transmitted by selected sections of the specimen, and (ii) film contrast—the slope of the characteristic curve of the film.

Definition or Resolution.—This refers to the sharpness of outline of the image, unsharpness being the extent of broadening of a line due to a lack of definition.

Scheme of Investigations

It will be seen from Table I that only certain factors governing the quality of a radiograph can be attributed directly to the size and nature of the gamma source ; these factors have been underlined. In order, therefore, to form comparisons of these factors, investigations were conducted under the following four main headings : (i) radiographic sensitivity, (ii) radiographic contrast, (iii) film grain size, (iv) theoretical considerations of unsharpness due to scattered radiation and definition due to geometry of exposure.

For the above investigations, radiographs were produced using the four gamma ray sources, the exposures being made through steel specimens consisting of rectangular blocks of varying thicknesses. In order that an accurate comparison of the effects of different sources can be made, all factors, other than those underlined, must be kept substantially constant, and to this end the test exposures were all made on the same type film, Kodak Industrex Type D, with front and back lead foil intensifying screens 0·005in thick. A standard processing technique was adopted using Kodak D19b developer, with eight minutes' development time at 65 deg. Fah. Radiographic background densities between 1·5 and 2·0 H and D units were aimed at, this being done to ensure all density measurements falling on the linear portion of the characteristic curve of the film, thus preserving the relationship between density and exposure.

Radiographic Sensitivity

An appreciation of the importance of radiographic sensitivity may be gained from a realisation that this is, in fact, a measure of the information that can be gleaned by scrutiny of a radiograph. In order to assess the sensitivity obtainable using the different sources, exposures were made through steel blocks of 1in, 2in, 3in and 4in thicknesses. These steel specimens had penetrameters fixed to the side nearer the source, thereby enabling the penetrameter sensitivities of the resultant radiographs to be noted. This series of exposures was repeated for each source in turn, at distances, source to film, of 6in, 12in, 24in and 36in. These thicknesses and distances had to be modified, however, and were, in fact, halved, for the exposures using iridium, this being due to the low energies of the gamma rays from this source and their consequent inability to penetrate up to 4in of steel in a reasonable time.

Families of curves showing percentage sensitivity as a function of specimen thickness at the selected distances were drawn from these results, and perusal of these curves (Figs. 1, 2, 3 and 4) gives a clear indication of the variations which can be expected by the use of the different sources.

Each curve corresponds to a given technique, and each exhibits a minimum position denoting optimum percentage sensitivity. These minima occur at different values of specimen thickness for the various sources of gamma rays, the appropriate points being 1·7in for radium and tantalum, 2in for cobalt and 0·5in for iridium.

In the limit, the value of sensitivity in each case tends towards infinity as specimen thickness approaches zero or the value of source-to-film distance, and, the rate of change of the slope of a curve away from its minimum point gives an indication of the range of thickness which may be radiographed simultaneously under the relevant conditions.

These curves thus supply information regarding the radiographic results which may be obtained for ideal steel specimens and thereby indicate the technique which can be employed most profitably for various subject thicknesses.

In subsequent sections of the article an attempt has been made to analyse the factors

* Density is the degree of blackening of a film and is defined by Hurter and Driffield as $D=\log_{10}(I_0/I_t)$, where I_0 is the light intensity incident on the film, and I_t is the light intensity transmitted by the film.

which give rise to the form of these sensitivity curves and to show how these factors, and, hence, the curves, may vary with the radiation source.

Radiographic Contrast

Radiographic contrast is a function of two variables—subject contrast and film contrast. The latter, as already indicated, has, for our purposes, been rendered a constant. Thus any contrast variation which is apparent with the use of the different sources must be due to variations in subject contrast, which, in turn, depends on radiation wavelength and scatter, together with specimen thickness which is controllable. The test exposures relating radiographic contrast were made using stepped steel wedges, each wedge having five steps, the difference in thickness between these steps being ¼in. The nominal thickness of a wedge was taken as the actual thickness of its centre step. Wedges of nominal thicknesses 1in, 2in, 3in and 4in were exposed in turn to the radium, cobalt and tantalum sources. As in the previous investigation these thicknesses were halved for the exposures using iridium. A fixed source-to-film distance of 18in was used for all the exposures, which were adjusted to give a density of between 1·5 and 2·0 H and D units on the centre step image. This is important, because it was at these nominal points that the contrast was to be related.

The resultant radiographic image densities were read on a densitometer, and the values thus found were duly corrected for beam divergence and plotted graphically against the appropriate specimen thicknesses. These curves, compiled for each source, gave from their slopes the rate of change of radiographic density with respect to specimen thickness at the several selected points.

The slope at the nominal point "t" (the relative contrast), was measured for each curve, and these values were correlated on a graph (Fig. 5), where relative contrast in density units per inch of steel specimen is shown as a function of specimen thickness. This provides a curve for each source giving the contrast to be expected when making an exposure on an ideal subject of any thickness up to 4in (2in in the case of iridium).

According to C. E. K. Mees the minimum perceptible film density difference at normal viewing levels of brightness is approximately 0·02 H and D units. There is, however, evidence that it may be considerably lower than this, possibly as low as 0·007 H and D units. If one assumes a value for minimum perceptible density difference, it is possible to determine from the relative contrast curves the sensitivity due to contrast as a function of specimen thickness. Assuming the lower value 0·007 (Fig. 7) gives the variation of contrast sensitivity with specimen thickness for various sources.

Consideration of the classical absorption laws enables a mathematical representation of contrast sensitivity to be derived.

Let x be specimen thickness and dx be thickness variation, giving respectively emergent beam intensities I_1 and I_2.

Now,

$$D=\gamma \log_{10}(It) \quad . \quad . \quad . \quad . \quad (11)$$

where D is density, γ is the film gradient, t the exposure time and I the emergent beam intensity.

Therefore,

$$D_1-D_2=\gamma(\log_{10}I_1t-\log_{10}I_2t) \quad . \quad (12)$$

$$=\gamma \log_{10}(I_1/I_2) \quad . \quad . \quad . \quad . \quad (13)$$

$$=(\gamma/2\cdot3)\log_e(I_1/I_2)=D_m \quad (14)$$

where D_m is the minimum perceptible density difference.

But,

$$I=I_0e^{-\mu x} \quad . \quad . \quad . \quad . \quad (15)$$

where I is the emergent beam intensity, I_0 the incident beam intensity, μ the absorption coefficient and x the specimen thickness.

From (14) and (15)

$$D_m=\frac{\gamma}{2\cdot3}\log_e\frac{e^{-\mu x}}{e^{-\mu(x+dx)}} \quad . \quad . \quad (16)$$

$$=\mu\gamma dx/2\cdot3 \quad . \quad . \quad . \quad . \quad . \quad (17)$$

By definition, sensitivity,

$$S=dx/x \quad . \quad . \quad . \quad . \quad . \quad (18)$$

$$=2\cdot3D_m/\mu\gamma x \quad . \quad . \quad . \quad (19)$$

$$=1\cdot61/\mu\gamma x \text{ per cent} \quad . \quad (20)$$

(for $D_m=0\cdot007$).

Thus for a constant μ,

$$S=k/x.$$

The form of this curve is a rectangular hyperbola, and, assuming $\gamma=4$ and substituting the appropriate value of μ for each source, theoretical sensitivity curves can be calculated and are shown in Fig. 6.

The difference between the calculated and the experimental curves is due to a reduction in contrast caused by an overlying density layer due to radiation scattered mainly by Compton collisions. The ratio of the intensities of the scattered radiation to the primary radiation increases with the thickness of the specimen, causing a reduction in contrast in the higher thickness ranges.

Film Grain Size

According to Gurney and Mott, the ionic crystals of the silver halides, which form the sensitive constituent of a photographic emulsion, are energised by radiation quanta which liberate electrons due to direct and secondary action. These electrons wander until they are taken up by microscopical sensitivity specks which are present in the crystals, thereby setting up localised electrostatic fields. Interstitial positively charged silver ions also present in the crystals are attracted to these sensitivity specks where they neutralise the electrons in forming atoms of silver. Above a certain size this aggregation of silver atoms becomes a latent image speck which has the power during development of catalysing the crystal, together with surrounding crystals, to form a metallic silver spot in the emulsion.

Experiment has shown that the energy of an X or gamma photon which impinges on a photographic emulsion has a direct effect on the size of the area which it activates. The greater the energy of the photon the larger the area activated. This is most probably due to the increase in kinetic energy of the liberated electrons and their consequent longer free path and greater secondary action.

This produces graininess giving rise to an unsharpness value, U_f, which tends to reduce the ultimate sensitivity. With modern film manufacturing techniques this factor is kept small in comparison with other unsharpness values and is thus of little practical significance.

Fig. 9 shows reproductions of exposed films which have been produced by (*a*) 220kV X-rays ; (*b*) iridium 192 gamma rays ; (*c*) radium gamma rays ; (*d*) tantalum 182 gamma rays ; (*e*) cobalt 60 gamma rays.

The exposures were made on Kodak Industrex Type D film, using 0·005in lead foil intensifying screens, the radiation in each case being filtered by 1in of steel. The effect of the filter and screens is to harden the radiation, but this is probably preferable as it more nearly approaches conditions of normal use. The illustrations show the grain size magnified fifty times, the one applying to 220kV radiation being included for comparative purposes. It is obvious that the grain size is smallest when X-radiation is used, and this must enhance definition, but any difference in grain size of the films taken by isotopes or radium is hard to detect.

The illustrations have been arranged in order of ascendant grain sizes, but for all practical purposes it may be said that when using the gamma ray sources, apart from iridium which gives a somewhat finer grain and thereby a slightly better rendition of detail, radium, cobalt and tantalum give grain sizes so nearly similar as to be indistinguishable.

Theoretical Considerations of Unsharpness and Definition

H. A. Klasens has shown that the total film unsharpness is not equal to the sum of the various unsharpness values (factors shown in Table II), but must be expressed as,

$$U_0=\sqrt[3]{U_g^3+U_f^3+U_s^3} \quad . \quad . \quad (21)$$

where U_0 is the total unsharpness, and U_g, U_f and U_s are unsharpness values due respectively to exposure geometry, film grain size and scattered radiation.

Of these three factors, U_g can be controlled, and so, by judicious choice of exposure distance, be made as small as desired. U_f, as indicated in the paragraph on grain size, varies very little over the range of gamma energies under consideration, and, by manufacturing techniques, is rendered relatively small. Thus the dominating factor in (21) above becomes U_s, unsharpness due to scattered radiation.

Unsharpness Due to Scattered Radiation.—The Klein-Nishina expression for the intensity distribution of scattered radiation gives a

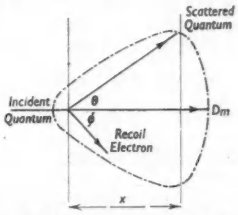


Fig. 10—Distribution of Scattered Radiation About a Point of Collision

method of determining theoretically the spread of a ray which is scattered by Compton collision at the outer surface of an absorber. This is the extreme case (see Fig. 10).

According to Klein and Nishina the ratio of the scattered to primary radiation is :

$$\frac{I_s}{I_p}=\left[1+a_0 \text{ vers}\,\theta\right]^{-3}\left[1+\frac{a_0^2 \text{ vers}^2\,\theta}{(1+\cos^2\theta)(1+a_0 \text{ vers}\,\theta)}\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

where

$$a_0=\frac{hv}{mc^2}$$

and

θ=scattering angle.

h=Planck's constant, $6\cdot55\times10^{-27}$.

v=frequency of vibration.

m=mass of an electron, $9\cdot10\times10^{-28}$ g.

c=radiation velocity, 3×10^{10} cm/sec.

For small angles, up to a density difference of 0·007 density units, the latter part of the equation approaches zero, leaving the Gordon-Dirac equation :

$$\frac{I_s}{I_p}=\left[1+a_0 \text{ vers}\,\theta\right]^{-3} \quad . \quad . \quad . \quad (23)$$

Because of the decrease in wavelength

after scattering, and the increase in distance travelled through the specimen, distance and attenuation factors must be included.

$$\frac{I_s}{I_p}=\left[1+a_0 \text{ vers } \theta\right]^{-3}\frac{1}{\cos^2\theta}\cdot\frac{e^{-\mu_s x/\cos\theta}}{e^{-\mu_0 x}} \quad . \quad (24)$$

where μ_0 is the absorption coefficient of the original ray and μ_s is the absorption coefficient of the scattered ray.

For the limited range under consideration,

$$\mu=\frac{1\cdot87}{a+2} \text{ (within 2 per cent)}$$

where

$$a=\frac{a_0}{1+a_0 \text{ vers } \theta}$$

and

$$a_0=h\nu/mc^2.$$

Taking the case for cobalt 60, mean energy 1·25 MeV,

$$a_0=2\cdot45.$$

Therefore,

$$\frac{I_s}{I_p}=\left[1+2\cdot45 \text{ vers } \theta\right]^{-3}\frac{1}{\cos^2\theta}\cdot\frac{e^{-\frac{1+2\cdot45 \text{ vers } \theta}{4\cdot45+4\cdot9 \text{ vers } \theta}\cdot\frac{1}{\cos\theta}}}{e^{-\frac{1}{4\cdot45}}} \quad . \quad (25)$$

This may be equated to the minimum perceptible density difference, since,

$$-\frac{2\cdot3D_m}{\gamma}=\log_e\frac{I_s}{I_p} \quad . \quad (26)$$

$$=-3\log_e\left[(1+2\cdot45 \text{ vers } \theta)\cos^{2/3}\theta\right]$$

$$\frac{1+2\cdot45 \text{ vers } \theta}{4\cdot45+4\cdot9 \text{ vers } \theta}\cdot\frac{1}{\cos\theta}+\frac{1}{4\cdot45} \quad . \quad (27)$$

Using values of 0·007 for D_m the minimum perceptible density difference and 4 for γ the film gradient, θ is approximately 2 deg.

Thus for a fixed observable density difference, θ will be fixed and U_s, unsharpness due to scattered radiation, will be directly proportional to x, the thickness of the specimen.

Considering the energy of the scattered radiation, relativity shows that if m is the mass of an electron at rest, its mass will be

$$m/\sqrt{1-\beta^2},$$

when travelling with a velocity V, and $\beta=V/c$.

Its kinetic energy will be

$$mc^2\left(\frac{1}{\sqrt{1-\beta^2}}-1\right).$$

From the law of conservation of energy,

Energy of incident quantum
=energy of scattered quantum+kinetic energy of electron.

Therefore,

$$h\nu=h\nu'+mc^2\left(\frac{1}{\sqrt{1-\beta^2}}-1\right) \quad . \quad (28)$$

and, resolving momentum in the line of incidence,

$$\frac{h\nu}{c}=\frac{h\nu'\cos\theta}{c}+\frac{mV}{\sqrt{1-\beta^2}}\cdot\cos\phi \quad . \quad (29)$$

and at right angles,

$$0=\frac{h\nu'\sin\theta}{c}+\frac{mV}{\sqrt{1-\beta^2}}\cdot\sin\phi \quad . \quad (30)$$

Solving these three equations,

$$\lambda'=\lambda+\frac{h}{mc}(1-\cos\theta) \quad . \quad (31)$$

where λ' is the wavelength of the scattered radiation corresponding to ν', the frequency of vibration.

From this equation it can be seen that the only factor which affects the change of wavelength from incident to scattered radiation is the angle of scatter θ, and for small values of θ, λ will vary only slightly.

Thus, for the purposes of these investigations it can be assumed that unsharpness due to scattered radiation will be similar for the four sources when they are used under the same conditions, and this assumption can be considered reasonable since the foregoing theoretical considerations of this factor show that although unsharpness due to scattering increases linearly with specimen thickness, any difference in energy of radiation (between the limits investigated) has little effect on diffusion of the image.

Definition Due to Geometry of Exposure.—Definition due to geometry of exposure is a function of the size of the emitting source and the distance between source, subject and film, a loss of sharpness being due to an increasing penumbral width, U_g.

For a given source size, s, as d, the source-to-object distance, decreases, or t, the specimen thickness, increases, U_g becomes larger and eventually dominates the total unsharpness value U_0. It is when these conditions hold that investigation proves of practical value. Any possible reduction in source-to-film distance which is still consistent with adequate definition allows, in accordance with the inverse square law, a reduction in exposure time, and, to the radiographer, time thus saved is often a distinct advantage.

The criterion of definition is the ultimate resolution of the eye and, for normal vision, this is approximately 1·5 minutes of arc subtended at the eye. At normal viewing distances this gives a value in the neighbourhood of 0·25mm. That is, a circle of diameter 0·25mm cannot be distinguished from a point by the unaided eye and, hence, nothing is achieved by reducing U_g below this value. The unaided eye will no longer be capable of further resolution.

Consideration of the geometry of exposure gives

$$d/t=s/U_g,$$

where d is the source-to-specimen distance, t is the specimen thickness, s the source width and U_g the penumbral width.

Since U_g is 0·25mm for minimum perceptible unsharpness, the d/t ratio should be $4s$ for optimum definition due to geometry. Perusal of the source sizes in Table II will indicate the various d/t ratios which satisfy this condition.

In practice there is seldom any object in trying to achieve this optimum value for U_g since in many cases it would be completely overshadowed by other unsharpness values. If, however, a minimum standard of radiographic technique is acceptable, it is possible to arrive at compromise values of source-to-film distance in relation to specimen thickness which will be consistent with adequate sensitivity.

This has been done in Fig. 8, which gives a curve for each source showing source-to-film distance as a function of specimen thickness for a constant sensitivity of 2 per cent. It must be borne in mind that this value of 2 per cent is purely arbitrary and depends largely on the kind of penetrameter used. A step penetrameter, whose clear edges give an easily discernible image, would, when indicating 2 per cent, correspond to a less searching technique than the more difficult-to-discern wire or ball penetrameters.

Conclusions

This survey of the three most widely used artificially produced radio-active isotopes, cobalt 60, tantalum 182 and iridium 192, has shown that in many respects they are largely complementary in nature and in their application to steel foundry radiography.

Specimen Thickness Range.—The range of thicknesses which can be efficiently and conveniently examined may be determined from the sensitivity curves (Figs. 1 to 4). Using cobalt 60, effective penetration can be accomplished through thicknesses ranging from 1in to 5in of steel and, with a somewhat diminishing sensitivity it is possible to radiograph up to 8in. The time required for an exposure depends on the activity available and on exposure geometry. The hard radiation, 1·25 MeV mean, from cobalt 60 renders it particularly useful in examining thicknesses of 3in and above, where softer radiation would be largely absorbed.

Tantalum 182 can cover the same range of thicknesses as cobalt 60, its mean energy being 1·125 MeV. However, the softer components in its spectrum enable slightly better radiographic contrast to be obtained than with the cobalt radiation, the effect of this increased contrast being most apparent in the region 1in to 2in.

Iridium 192 finds its application in the lower range of thicknesses, from ½in to 2½in. Its gamma spectrum contains no hard component to mask the medium and soft energies, the mean being at 0·5 MeV. High relative contrast is thus a characteristic of iridium exposures, and, accompanying this, as one

Table II—*Physical Constants of Sources Used in Investigations*

Source	Half life	Energy spectrum	Radiation (from unshielded gammas)	Source size	Specific activity	Activity of source used in investigations
Radium	1590 years	Many energies between 0·24 MeV and 2·02 MeV. Most important: 0·60 MeV, 1·12 MeV and 1·76 MeV	0·84 milliroentgen per hour at 1m	Cylinder: 7·5mm length, 5·5mm diameter	1 curie per gramme...	200 mgms
Cobalt 60	5·3 years...	1·17 MeV and 1·33 MeV ...	1·3 milliroentgens per hour at 1m	Cylinder, 6mm length, 6mm diameter	(For pile factor 1): 1 week, 2·1 Mc/gramme; 4 weeks, 8·5 Mc/gramme. Saturation, 830 Mc/gramme	950 millicuries
Tantalum 182	120 days...	Many gamma energies down to 46 keV. Most important: 1·22 MeV, 1·13 MeV, and 0·22 MeV	0·605 milliroentgen per hour at 1m	Cylinder, 6mm length, 6mm diameter	(For pile factor 1): 1 week, 5·2 Mc/gramme; 4 weeks, 20 Mc/gramme. Saturation, 190 Mc/gramme	360 millicuries
Iridium 192	70 days	Twelve gammas. Most important: 0·61 MeV, 0·60 MeV, 0·58 MeV and 0·13 MeV	0·27 milliroentgen per hour at 1m	Cylinder, 2mm length, 2mm diameter	(For pile factor 1): 1 week, 160 Mc/gramme; 4 weeks, 600 Mc/gramme. Saturation, 3·4 curies/gramme	300 millicuries

Pile factor $1=1\times10^{11}$ neutrons/cm²/sec for 120 hours per week.

would expect, high attenuation and a low limit of penetration.

Specific Activities and Activation Times.—The isotopes are supplied in the form of activated metal pellets which, as indicated in Table II, are capable of attaining high specific activities. Radium possesses a constant specific activity of 1 curie per gramme. However, since the normal commercial form supplied for radiography is usually an anhydrous salt, the intensity of radiation from a given size capsule of nominal radium content is much less than those available from similarly sized artificially produced isotopes.

The activation times for the isotopes are, very roughly, proportional to their half lives, cobalt 60 requiring a much longer irradiation in the atomic pile to acquire a given intensity than does iridium or tantalum. Irradiation times in the Harwell pile BEPO to bring 6×6mm sources to an activity of 500 millicuries are : cobalt 60, thirty months ; tantalum 182, ten weeks ; iridium 192, two weeks.

Tantalum 182 thus proved a very valuable aid to radiography during the initial period when cobalt 60 was not available, but, in view of its relatively short half life, it has been largely replaced in radiographic laboratories by the longer-lived cobalt. Iridium 192, with its low energy gammas and rapid activation to high values for small physical dimensions, has a very definite application.

Special Applications.—The range of thicknesses covered by the isotopes having already been discussed, it only remains to review their application to casting radiography.

A gamma ray technique using iridium 192 can be advantageously employed in the following circumstances :—

(i) On thicknesses up to 2½in, where the subject contrast is not too great.

(ii) With small source-to-film distances (i.e. small diameter rings, pipes and box-section castings).

(iii) When high contrast is desired.

(iv) Where good definition is required.

The use of iridium is precluded where the section to be radiographed is over, say, 3in, or where the subject contrast is too great. Consequential upon using small source-to-film distances the field of examination will be small and considerable distortion of the image may be present.

Tantalum 182 and cobalt 60 each cover the same range of steel thickness, but the former can be more profitably employed in the following circumstances :—

(i) On sections between, say, 1in and 4in.

(ii) Where the subject contrast is too great for the use of iridium (i.e. castings of a complex nature and a diversity of section).

Cobalt 60 finds its role in the examination of castings having heavy sections over, say, 3in. Its high specific activity and hard radiation render it particularly suitable for thick flanges, bosses and heavy plates, whilst its low relative contrast enables a large range of thicknesses to be examined simultaneously—a useful attribute in the radiography of spherical or cylindrical solid sections.

Thus when used conjointly these three sources form a valuable radiographic tool. They provide a choice of radiation quality at gamma energies which enables thicknesses ranging from ½in to 5in of steel to be examined with an adequate degree of radiographic contrast and sensitivity. Radiation from radium, which has a complex spectrum containing both hard and soft gammas, gives results which are comparable to those obtainable by the use of tantalum. If, therefore, radium is available it proves as effective as tantalum in forming the link in energy between iridium and cobalt.

Appendix

Cost of Gamma Ray Sources for Radiography.—The irradiation charges for artificially produced isotopes are, for 1 curie : Cobalt 60, £40 ; tantalum 182, £20 ; iridium 192, £15.

Assuming a useful period of two half lives, and an initial intensity of 1 curie, the costs per annum for continuous supplies would be : Cobalt 60, £3·77 ; tantalum 182, £30·41 ; iridium 192, £39·1.

Note.—The average intensity over time t, commencing with an initial intensity I_0, is :

$$I_m = \frac{1}{t}\int_0^t I_0 e^{-kt}dt \quad . \quad . \quad . \quad . \quad (1)$$

$$= \frac{I_0}{t}\left[\frac{1}{-k}e^{-kt}\right]_0^t \quad . \quad . \quad . \quad (2)$$

$$= -\frac{I_0}{kt}\left[e^{-kt}-1\right] \quad . \quad . \quad . \quad (3)$$

For t equal to two half life periods and I_0 1 curie I_m is approximately 550 millicuries.

The rental charges for radium are based on £225 per gramme per annum and *pro rata*, with a minimum charge of £25. Thus, a 550 milligramme radium source could be hired for a yearly rental of £123. These comparative figures serve to indicate the relative prices of the various gamma ray sources and emphasise the low cost of cobalt 60.

Acknowledgment

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Molecular Bonded Bimetallic Components

In this article mention is made of the "Al-Fin" bimetallic molecular bonding process, and its principal applications. It concludes with some recent and important specialised uses in the general engineering and military spheres.

DURING a visit last week to the Lymington works of Wellworthy, Ltd., we had the opportunity of seeing some of the more recent automotive applications of the "Al-Fin" bimetallic molecular bonding process. The achievement of such a process bonding aluminium and its alloys with ferrous metals had long been sought before the war, notably in connection with the air-cooled cylinders of aircraft engines. Depending on the heat transfer characteristics of the interface a light alloy finned barrel and a ferrous liner offered considerable advantages. The construction combined the thermal and weight characteristics of aluminium with the strength and wear and impact resistance of the ferrous liner, enabling a better power/weight ratio to be attained and a lower cylinder operating temperature, thus permitting higher thermal loadings and the use of higher octane fuels. For reference purposes some comparative material thermal/weight characteristics are reproduced here :

Comparative Thermal Conductivity and Weight

Material	Thermal conductivity at 100 deg. Cent. O.G.S. units	Thermal conductivity per unit of weight
Silver	1·00	1·00
Copper	0·90	1·06
Steel	0·107	0·14
Cast iron	0·052	0·06
L.35 (Y) alloy	0·40	1·54
99·4 per cent pure aluminium	0·54	2·09

One of the oldest methods consists of shrink fitting an aluminium alloy muff carrying cooling fins around the steel barrel. Pure aluminium is too soft for a shrink fitting as the joint would loosen under repeated heatings and coolings. Using an alloy the immediate result is a loss of approximately 30 per cent in heat conductivity. In addition, even the finest machining of the mating surfaces leaves appreciable variations in the degree of mechanical contact. Theoretically, the contact area of the joint would not exceed 50 per cent, but in actual practice, where operating temperatures are high, the different rates of expansion of the two metals tend to reduce the contact still more. The conductivity is still further reduced by oxide on adjoining surfaces, foreign solid material separating the surfaces, a gas film, poor mechanical contact, and temperature drop characteristics of surfaces in mechanical contact.

The difficulties of securing a chemical bond had arisen principally from the oxidisation which aluminium and its alloys readily undergo particularly at elevated temperatures, thus forming a non-metallic film on the interface. This problem, it will be recalled, had been overcome by Wellworthy, Ltd., in 1946, but it was then revealed that a basically similar process had been patented by the Fairchild Engine and Airplane Corporation, of Farmingdale, New York, and operated by it in wartime secrecy since 1941. The "Al-Fin" process derives its name from the aeronautical cylinder application which inspired its development and the comparative graphs reproduced in Fig. 1 are due to Professor Kayan, of Columbia University, following some early work on an "Al-Fin" barrel. Wellworthy, Ltd., acknowledged the prior claim to the process and now operates it under licence.

The process consists of three stages. In the first stage, the insert material is treated to present a chemically clean, reactive surface, for the second stage of the process. This stage consists of aluminising the insert under controlled conditions, so as to form on the insert surface a complex layer of iron aluminides, normally referred to by the collective misnomer $FeAl_3$, which is in solid solution with the insert material and in solution with the molten aluminium coating. The treated insert is then placed in the mould or die which is then filled, whilst the bond layer is still molten, with the desired aluminium or aluminium alloy, thus effecting a molecular bond between the dissimilar materials. The process is purely a foundry operation, and thus it is not applicable to the joining of finished components by processes such as welding or brazing.

The interface is complex in nature, and varies with insert material and bonding bath composition ; briefly, there exists a combination of three phases of binary compounds of iron and aluminium, the composition varying across the interface to form with the least iron content on the casting side the phase $FeAl_3$ (or Fe_2Al_5) in solution with aluminium, a second phase which may be taken as $FeAl_2$, and an unidentified phase of higher iron content, these phases being collectively referred to as Fe_xAl_y, with an average thickness of 0·001in. Identification of phases present in a layer of this thickness is difficult and work is in hand, using automicro-radiographic and back-scatter X-ray diffraction techniques, in the hope that more knowledge of the composition of the bond layer will be forthcoming.

The mechanical properties of the bond layer vary slightly with the bond bath composition, the Knoop Micro-Hardness Index (Tukon) being between 600 and 900 D.P.N. With correc-

tions for residual hoop stresses, the shear stress averages 3·5 tons per square inch, with an average tensile strength between 6 to 8 tons per square inch, these figures being maintained at temperatures up to 250 deg. Cent. due to the intermetallic nature of the interface. The bond layer is oil tight, gas tight, and vacuum tight, and has operated at a temperature of −193 deg. Cent. without failure. The bond layer is vibration proof, and transmits stresses and strains without amassing local concentration or stress build up. Another important property of the bond layer is that, again due to its metallic nature, it transmits heat energy with an efficiency of nearly 100 per cent ; it may thus be seen that the bond layer is mechanically and physically efficient, and, in the case of pure aluminium, is mechanically stronger than the cast material.

The ferrous member remains below the surface of the metal until the aluminium has attacked the iron and the bond is complete. The liner is then placed in the die and the casting metal poured in the normal manner forming the extended fin section. It is noticeable that while the molten metal is rising in the mould it is drawn up by the molten interface material on the surface of the iron liner forming a meniscus similar to that between water and the wet side of a glass, and for this reason the liner is described as being " wetted." Any oxide formed on the melted surface by contact with the air is peeled off by the rising metal and floats to the surface of the casting, leaving a perfect, clean intermetallic bond between the alloy and cast iron liner.

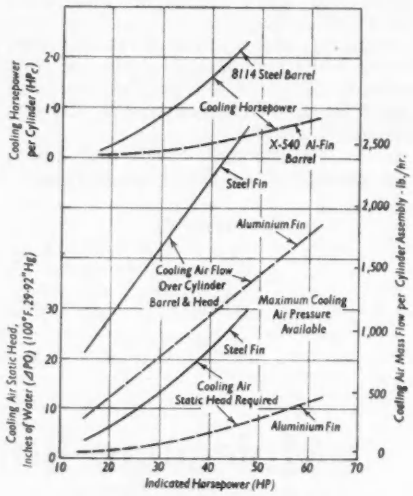
The way in which the casting metal flows on to a " wetted " surface has a further advantage as with ferrous inserts of complex section the alloy can be relied upon to flow over the entire surface, and is, therefore, in intimate contact with the insert over its whole area. This is stated to be unusual, for if a non-bonded bimetal casting is sectioned cavitation round the insert will be apparent.

The bond has an extremely high compressive stress. An aluminium coated steel strip was prepared and subjected to rolling with reductions in the steel and aluminium of up to 75 per cent, yet the thickness of the bond, on examination, remained the same.

In Fig. 2 we show the general arrangement of the new aluminium foundry at Lymington. Alternate melting baths in each lane are served by an oscillating dip stick actuated by cams from an overhead shaft. The member to be coated is secured to this stick so that during its total immersion it is cyclically moved up and down. The remaining baths are used to supply the gravity die casting stations which lie alongside the lines of baths. Between them are gas-fired heating stoves for preheating the ferrous members before dipping.

The bimetal motor-cycle cylinder remains the most extensive application of this process.

Tests conducted, it is claimed, have shown that bimetallic barrels under equal operating conditions have barrel temperatures 30 deg. to 50 deg. Cent. lower than normally found with conventional cylinder barrels, and that for equal cooling conditions, the optimum permissible power output could be theoretically doubled, whilst still obtaining a weight saving of 50 per cent, as well as an increase in bore life and a saving in oil consumption.



Cooling air temperature 100 deg. Fah.
Average barrel temperature 295 deg. Fah.

Fig. 1—Comparison of Cooling Requirements for a Cylinder Assembly Provided with a Standard United States Navy Barrel and "Al-Fin" Barrel-Smooth Flow Baffles with Standard Cylinder Head

It is also claimed that the bonded cylinders were thermally as good as hard chromium-plated aluminium cylinders, especially as the production of these latter items is not possible in super-purity aluminium, but necessitates the use of less efficient complex, but stronger alloys. The " Al-Fin " method is claimed to be 5 to 10 per cent cheaper than the one with the hard chromium-plated bearing surface, whilst the cost of a rebore which can be achieved to a diameter of 0·060in is about 50 per cent that of stripping, reboring and replating.

Another bimetallic component now being made by Wellworthy, Ltd., is the cylinder head itself. When produced in light alloy cylinder heads suffered from disadvantages caused by stripped sparking plug and valve seat insert threads, which caused rattles, loss of compression and possible piston crown damage. The cylinder head is produced with a hemispherical cast iron skull bonded to the light alloy body in which the valve seat and sparking plug threads are screwed in the cast iron member. Thermal dissipation and gas leakage are, by this means, eliminated.

In the case of light alloy diesel pistons particularly, the top ring groove, due to heavy wear or corrosion, has proved the weakest part of the piston. The use of a ferrous ring groove carrier introduced the difficulties of retaining it tightly due to the different thermal expansion coefficients of the two metals. The " Al-Fin " process has consequently been usefully employed in the large-scale manufacture of these units to bond the carrier to the piston which is diecast about it. Also in production are light alloy pistons with a bonded ferrous insert in the crown at the site of maximum corrosion.

Bimetallic brake drums are another application of the process now in production for cars in the high-speed category (Fig 3). The thermal loading of a brake drum necessitates the provision of an adequate heat reservoir as well as the facility for heat dissipation. Nevertheless, it is stated that where a drum of adequate size can be fitted and provision made for positive air flow over the brake fin belt, highly satisfactory braking conditions can be achieved with a weight saving of the order of 40 per cent. These brake drums utilise a relatively thin cast iron friction liner, around which is cast an aluminium back wall and fin belt.

A further application of the process is in the manufacture of aluminium bearings bonded to a steel back wall ; these bonded bimetallic bearings offer the advantage that the excellent bearing properties of the aluminium 6 per cent tin-bearing alloys may be used with the steel back wall supporting the " crush " and structural loading. Although aluminium alloy bearings have long been used, it has always been necessary to use a heavy radial section to support such loads, and also to make alloying additions to increase the strength of the alloy. Additionally, by the use of a lead-indium or lead-tin overlay such bearings are comparable in characteristics to those of pure silver.

Many other recent applications of the process now lie outside the purely automobile and engine field, which nurtured it and are mentioned here.

In an endeavour to save operational weight, Roots type blower lobes have been produced with the drive shaft bonded to cast aluminium alloy lobes ; this method of manufacture results in even stress concentration over the entire shaft surface, and is thereby superior to an interference fitted component of similar design. Again, in a similar manner, control surfaces or wings for use on guided weapons have been manufactured as bimetallic castings with an alloy steel actuator spar pivot being cast and bonded to an aluminium alloy wing, thus increasing its flexible strength and eliminating the necessity for elaborate control shaft configuration and making production quicker and cheaper. A recent development of this application is to bond also an investment cast alloy steel leading edge to the light alloy wing section which may be subjected to high

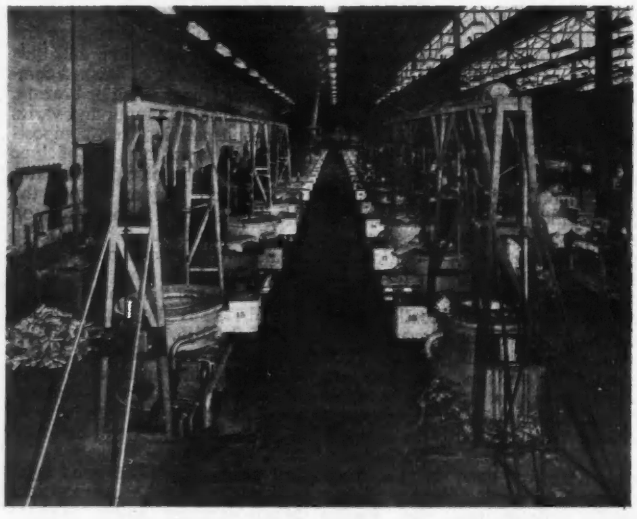


Fig. 2—Furnaces in Aluminium Foundry at Lymington

Fig. 3—Machining Bonded Brake Drums

mechanical, frictional and thermal loadings under supersonic flight conditions.

The process has been used to solve problems presented in nuclear engineering, as with the low half-life of aluminium and its freedom from neutron capture, components may be made in aluminium with ferrous inserts of the minimum permissible size. In the domestic sphere the production of bimetallic electric iron sole plates has been introduced. Since the war many million sole plates have been manufactured as gravity or pressure die castings and subsequently polished, but due to the occurrence of inherent sub-surface porosity, polishing rejects are found to be high, i.e. 20 to 30 per cent, and in use scratches and burns are often produced, by fasteners, due to the soft nature of the material. With steam irons and coarse materials such as linen, staining often occurs due to decomposition of the alloying constituents present. By bonding a thin (20 S.W.G.) sheet of stainless steel to the sole plate base it is possible to enhance its appearance, improve its using qualities and decrease 100 per cent the polishing rejects.

Using the heat transfer characteristics of bonded components, many varied types of heat exchangers have been produced, ranging from exhaust gas exchangers for aircraft cabin heating to large tube cluster-formed rocket motor combustion chambers, in which heat is exchanged from the combustion chamber to its fuel. The process is being used extensively in high vacuum and thermionic engineering, where its molecular sealing and anti-spluttering characteristics were required. Electric generators, motors and inverters and eddy current clutches, have been redesigned with the laminations of core pieces bonded integrally to the cast housing, where by more efficient heat transfer and more rigid design, faster running speeds, output frequency and pole flux has been made possible.

More recently bimetallic torpedo propellers have been manufactured with stainless steel blades, bonded to an aluminium alloy hub, and by this design the low modulus of elasticity of the light alloy is utilised to lower the shock loading of the blades upon aerial launching, minimising distortion, and decreasing the possibility of misruns and self-inflicted damage. Also, extensive development work is being conducted both here and in the United States, on the production of bimetallic jet engine stator compressor blades, using preformed aerofoil sectioned blading of the desired composition molecularly bonded and cast to an aluminium alloy root of a configuration necessary to mate with the annulus ring of the rotor.

Stainless steel cooking utensils such as frying pans are popular, due to their appearance and cleanliness, but because of the low thermal conductivity of this material uneven heating occurs, especially when using an intense flame. To effect even heat distribution, a layer of aluminium is bonded to the base of the pan. Tests conducted have shown that with a point source a drop of 180 deg. Fah. is experienced at a 4in radius with normal utensils, whilst with a bonded article the temperature drop is only 50 deg. Fah. Such utensils have recently been placed in full-scale production.

There are more variables to be considered in the design of bimetallic bonded castings than in normal casting, as due to the difference in rates of thermal expansion of the dissimilar materials, each application has to be studied on its own merits. Consideration has to be given not only to the temperatures at which the insert is raised during the bonding and casting, but also to the temperatures at which the component is subjected during operation, so that the stresses involved may be calculated and correction made in order to keep such stresses below the rupture stress of the bond layer. Such correction is achieved in three ways. Either the alloy section is made weak enough to yield below the bond shear stress which entails using an alloy with high ductility like D.T.D.272 (5 per cent Si) or pure aluminium ; or when a high-strength alloy such as RR.53 is necessary, by using as thin an insert section as is possible, so that it yields before the maximum bond stress is reached ; or by using insert material which has approximately the same coefficient of thermal expansion as the alloy, e.g. austenitic high-nickel cast iron ("Ni-Resist"), and an alloy such as "Lo-Ex," the relative difference in expansion coefficients being 0·00002in per inch per deg. Cent. Other design considerations are normal to conventional practice, such as the desirability of no sharp corners, or rapid changes of section, and for a general rule where the alloy is dispersed around the insert, manufacture is relatively simple, but when the alloy is dispersed inside an insert, such as a bearing shell, the stresses involved must be calculated mathematically, and often the designer is requested to modify his suggestion slightly to aid the foundryman.

Annealing may take place with some materials when they are subjected to bonding temperatures in the region of 700 deg. Cent., although unless the insert is of particularly heavy section bonding is normally effected within three to five minutes, which interval is normally too short to commence the annealing action. The transition point of most materials used is above normal bonding temperatures, but in some cases, a loss in ultimate tensile stress and yield is found, and where the ultimate properties of a specific material are required a change to a higher strength material is sometimes necessary and advocated. In some cases, however, this short time high-temperature treatment actually improves Izod and elongation figures, whilst not altering materially the yield and ultimate tensile stress figures.

American Engineering News

(By Our American Correspondent)

Industrial Participation in Nuclear Power Plant

The U.S. Atomic Energy Commission has renewed its invitation to private American industry to submit proposals for the investment of capital in the recently announced scheme to build a full-scale nuclear reactor for generating electric power. Since the initial announcement, the Commission has discussed with several organisations proposals for building with private funds the steam turbine and electrical generating portions of the project and for operating the entire power plant. The site of the 60MW atomic power plant has not yet been chosen. Although the A.E.C. announced in October that sites near the gaseous diffusion plants for the separation of uranium 235 would be considered, it has now been stated that the attractiveness of proposals involving private financing for the steam and the electric generating portions of the plant and for operating the plant would considerably influence the selection of a plant site.

Plastic Bodies on Chevrolet Cars

It is stated that the Chevrolet Division of the General Motors Corporation is starting the volume production of all-plastic bodies to be used on its "Corvette" sports car. Experiments have indicated that a great advantage to be gained from large laminated polyester mouldings is low tooling cost and short transition time between drawing board and production line. It has been estimated that the entire tooling cost for the sixty plastic mouldings that make up the body, dash and underbody of the "Corvette" will be under 500,000 dollars. The same body in steel would require dies costing about 4,500,000 dollars. With only limited production, at present all the plastic components that go into the body are produced by "lay-up bag" moulding. Woven or compacted mats of glass fibres are laid on mahogany moulds, painted or sprayed with liquid polyester resin and catalyst, and then placed, together with the mould, inside a large airtight bag. The air is then exhausted from the bag and atmospheric pressure moulds the plastic to the die as curing takes place. This process is not only slow and cumbersome, but produces a rough surface that must be sanded before finishing. A much better finish can be obtained from matched metal dies, which also can be heated to provide a faster curing cycle. New facilities at Ashtabula, Ohio, which were completed in December, 1953, will use the matched die process. The final finishing of the polyester mouldings for the "Corvette" results in a paint surface similar to the finish on steel automobile bodies. The basic body components are fabricated in an unpigmented colourless state and are coated with a baking primer and a final coat of medium-baking, synthetic enamel. The enamel and primer fill the pores in the moulding and prevent water adsorption by capillary action. The glass laminate bodies have a better strength-to-weight ratio than steel, and the superior resilience of the plastic eliminates denting. If the skin is punctured or torn by severe stress, repairs can be made quite simply with a patch of glass fibre and plastic. It is claimed that well-made repairs are virtually invisible and are quite strong. Little difficulty has been experienced in fastening the plastic body to the frame of the car, as the coefficient of expansion of plastic is close enough to that of steel to allow direct bolting to structural members. Plastic-to-plastic joints on the body utilise both bolting and adhesive bonding. With production of the plastic sports car scheduled for 1000 per month during 1954, it will be scarcely more than a pilot operation compared to the total car production in the United States. But the performance of these vehicles will no doubt be watched with interest by both the public and engineers concerned with automotive development.

Construction of Diversion Dam on the Missouri River

The U.S. Department of the Interior has approved plans for the construction of a diversion dam on the Missouri River at the Little Porcupine Creek site, 22 miles downstream from the Fort Peck dam. The dam is a key structure in a unit of the Missouri River Basin reclamation project which would ultimately supply water to some 100,000 acres of land in north-eastern Montana. The Congressional appropriations committees, while approving funds to initiate construction, raised some question concerning an alternate plan to supply the irrigation water by pumping directly from the river, and the Secretary of the Interior was directed to have a board of engineers advise him before reaching a decision. The board found that either method is feasible from an engineering point of view and that the initial construction cost of the pumping unit would be lower than that of the construction of a diversion dam and canals. However, the board found that because of the vagaries and heavy silting of the river which, in the past, has shifted its channel as much as a mile at the site of the proposed pumping plant, future operation and maintenance of a pumping plant would be subject to hazard and unpredictable costs. On the other hand, the board found that "construction of the diversion dam is entirely feasible and its construction would eliminate all uncertainties as compared to the pumping plant. In view of the probability of a minimum of operating and maintenance difficulties by the construction of a diversion dam and the existence of some operating hazards in the case of the pumping plant, it is the opinion of this Board that a substantial increased cost of constructing the diversion dam is justified as compared to the cost of constructing the pumping plant."

Hydro-electric power production is possible at the diversion dam but is not contemplated at this time although penstocks and other basic structures which are a part of the dam proper, will be installed. The Senate Appropriations Committee specifically directed that no power generating installations should be made at the dam without specific allocation of funds for that purpose by the U.S. Congress. The total construction cost of the diversion dam without the power facilities is estimated at 54,254,000 dollars compared with 44,181,000 dollars for the pumping plant. However, annual operation and maintenance costs of the diversion plan are estimated at 354,000 dollars compared with 430,000 dollars for the pumping plant, the big difference in operating costs being due to the power required to operate the pumping plant.

We have received from the Royal Technical College, Glasgow, a bulletin entitled "Research Report," which replaces the former *Journal* of the College. It provides a brief record of the research work in progress and lists some publications and the titles of theses approved for higher degrees.

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ADVANCES IN NUCLEAR POWER TECHNOLOGY

The delivery, before the "Mechanicals," of the James Clayton lecture on "Nuclear Reactors and Power Production," by Sir Christopher Hinton, the reprinting of which we conclude in this issue, coincided closely with the presentation to Parliament for second reading of the Atomic Energy Authority Bill. Sir Christopher certainly had no such intention in mind; yet his lecture reveals, we think, how necessary it has become to alter the organisation under which atomic research has been conducted since the war; and how essential it is becoming to make more technical information generally available. It would be profitless to speculate upon what the lecture would have been like if security regulations had not recently been relaxed. Even as it is, the lecture bears witness to the fact that many details are still being kept secret, as can, for example, be observed by comparing the amount of detail Sir Christopher was able to reveal about the British Experimental Pile at Harwell with the much more sketchy description of the Windscale plant and the total lack of direct reference at all to Dounreay. Yet within the limitations still imposed for reasons of security Sir Christopher was able to show how complex, how novel and how interesting are the problems that engineers are called upon to solve in the construction of atomic reactors.

The time is now fast approaching when industry is likely to become economically interested in the design and manufacture of nuclear power plants. According to Sir Christopher, "the estimated cost of electricity generation from a prototype thermal reactor is in the neighbourhood of a penny a unit," only "about 50 per cent higher than the average cost of generation from coal-fired power stations." He seems to be in no doubt that, following experience with prototypes (one is already under construction at Calder Hall in Cumberland), it should be possible to bring the figure down to 0·8 pence per unit, so that should the price of coal rise "it would not be surprising if nuclear power became fully competitive within ten years." Indeed, the basic research stages, those of discovering first whether the generation of power is practicable and of building prototypes to illuminate what problems have to be overcome is already far advanced. When, within a few years, the Dounreay plant, a big fast reactor of the breeder type, comes into operation experience will have been gained in the design and operation of the whole range from slow, through moderate, to fast reactors. Thereafter the problems to be faced will be of a kind with which industry is more familiar than a research organisation, those not merely of overcoming technical difficulties, but overcoming them cheaply. Some idea of the technical problems involved was given by Sir Christopher in his lecture. They make fascinating reading. The structural and even the chemical implications of atomic power do not perhaps carry engineers into altogether unfamiliar regions. But, to quote Sir Christopher, "the limiting factor in reactor design is the performance of the fuel element." There the engineer is invited to step upon ground hardly at all surveyed before. A fuel element consists of a can containing uranium, mounted in the pile. The container must stand up to intense irradiation, accommodate growth and distortion of the uranium, do so without bursting or allowing leakage of active fission products into the coolant stream, stand up to large internal pressures, high temperatures and high thermal stresses, and yet be removable with certainty "at the end of a proper period of irradiation or in the event of individual failure, despite any distortion that may have taken place." Only a limited range of materials has physical, chemical and atomic properties suitable for the manufacture of such containers. Again, novel problems of heat transfer are involved; and the faster the reactor the more involved they become, for fast reactors have small cores. The circulation of coolant under pressures of 500 or even 1000 lb per square inch has to be conceived; and a heat flux of the order of 3×10^6 B.Th.U. per hour per square foot has to be accommodated. For a fast reactor there are believed to be advantages in the use of a liquid metal coolant. Safety, too, has to be considered. Natural uranium reactors can be made inherently safe; but not so reactors using enriched uranium. Engineers then have the task of designing a vessel to contain the reactor, capable of withstanding the pressure should an accident happen and the core disintegrate. At Schenectady a reactor of that kind is housed in a steel sphere 225ft in diameter. The reactor to be built at Dounreay will be similarly enclosed.

Solutions have, of course, been found for these technical problems. But if nuclear power is to become competitive with power from conventional fuels the solutions found must be not only technically satisfactory, but also relatively cheap. Problems of that kind, we believe, will be most rapidly resolved when industrial firms become interested in taking up nuclear power plants as a normal line of manufacture—a development foreshadowed by the remarks of Sir David Eccles in introducing the Atomic Energy Authority Bill to the House. Then it will be desirable to reveal openly details of nuclear power plant design for the kind of free general discussion that is so fruitful in advancing design, whether held privately between individuals or publicly before an Institution. Nor, indeed, whether or not the military security people still desire to draw a veil of secrecy over engineering developments in nuclear power, do we think it will be possible very much longer to do so outside the field of advanced research. For within the next decade, as a consequence of the actions of the new Atomic Energy Authority to be set up under the Bill, very many more people than at present will and should become acquainted with the technology of nuclear power. That Authority will, for example, to quote the Minister of Works, "place research contracts with universities and with industry," and it will "consider the education of outside scientists and engineers to be a very important part of its task." The Minister also mentioned the setting up of a school of reactor technology, "where engineers from industry can learn about the fundamental principles of reactor design and be brought up against the many technical problems which designers have to solve." The British Electricity Authority will be encouraged to place orders for nuclear power plants with industrial firms. The only reason for further secrecy about nuclear power plants is the intimate connection between the generation of power and the production of fissile material for atomic weapons. It is an intimacy that can be exaggerated and we believe the new Authority will be able to find the means, without revealing too much about atomic weapons design and production, progressively to free power plant technology from the shackles of secrecy. If "the greatest contribution which this country can make to Commonwealth development in this century," as Sir David Eccles remarked, "is in atomic power," the lifting of the veil of secrecy is a change devoutly to be hoped for.

PRESTRESSED STEEL

Prestressed concrete has now had a successful vogue in structural engineering for several years, and it is not surprising that the reputation this method of construction has achieved should lead its exponents to consider other applications of the same principle. It is natural that thought should be given to its possibilities with the other principal structural material—structural steel—as has, in fact, been the case. Recent developments in this sphere were discussed at the Institution of Structural Engineers on February 21st, when a paper entitled "Prestressed Steel Lattice Girders," by R. A. Sefton Jenkins, was presented for discussion. The basic fact leading to the prestressing of concrete—that concrete is relatively strong in compression and weak in tension—is sufficiently obvious, but in the case of steel the reasons are purely economic. It has been explained that if a mild steel tie member with a working stress of 20,000 lb per square inch is replaced by high-tensile steel wires, which may be stressed to 140,000 lb per square inch, only one-seventh of the weight necessary with mild steel will be needed. The cost of the high-tensile steel is about three times that of mild steel, so that in this simplified example there would be a considerable saving in weight and cost. In fact, the deflections in such a case would be multiplied by seven, and the actual application is much more complex than this example, which simply indicates that appreciable economies are possible. Prestressing is a necessary part of the process because the deflection of the high-tensile steel is large and without prestressing it would not carry a high enough load. Professor Magnel expounded these ideas in a paper presented to the Institution in November, 1950. He has since constructed a prestressed steel main beam for a hangar at Melsbroek Airport. It consists of two 250ft truss spans, continuous over the central support, which are prestressed by high-tensile steel wires (anchored by the same method as in prestressed concrete), positioned within the depth of the truss in the tensile zone (i.e. near the top of the truss over the central support and near the bottom in the other parts of its length). An economy of up to 26 per cent in weight and 18 per cent in cost, principally for spans of 200ft or over with heavy dead loads is claimed.

The method adopted by Mr. Jenkins is rather different. His paper describes the design and construction of a factory recently erected at Harlow, and gives results of loading tests on the main beams. The familiar king post and ties or queen posts and tie arrangements are modified in this design, and the system consists essentially of a lattice box-beam of constant cross section, sloping at each end and horizontal in the centre, with straight tie bars underneath it connecting its ends, very much like a tied portal. The ties are tensioned with turnbuckles. An additional "queen post" tie arrangement under the horizontal central part of the beam is shown in one design. In this case prestressing of the ties induces tension in the top flange of the girder and compression in the lower one, a condition which is in opposition to the effect of the dead and live loads. These beams span 60ft and the largest individual member is only a 1¾in by 1¾in by ¼in angle. The weight of the steelwork amounts to 2·92 lb per square foot of covered area with high-tensile ties, and 3·4 lb per square foot with mild steel ties, neglecting the weight of the roof monitors built in this particular case; and the cost is about £115 per ton, it was stated in the discussion. Mr. Jenkins compared this arrangement with the one adopted by Professor Magnel, and gave figures for a girder with the same total structural depth and other conditions as for one of the professor's design, comprising a shallower girder with prestressed ties below it, which indicated even greater savings in weight and cost. Another exponent of this method of construction is Mr. F. J. Samuely, who has built several steel structures which make use of the principles of prestressing. During the course of the discussion he mentioned the "Skylon" built for the Festival of Britain, in which the supporting cables were prestressed to give the structure rigidity against the dynamic effects of the wind. This design was described in THE ENGINEER of May 11, 1951; a similar principle, it may be noted, has been employed in prestressing the stay wires of tall television masts. The most interesting of Mr. Samuely's achievements are two workshops, one about 78ft. square and the other 90ft square, built to a similar design, without any intermediate columns. They have pitched roofs, the ridges being 22ft 6in apart and 5ft 2in above the valleys (in the case of the 90ft square structure), but the roof trusses are placed in the sloping plane of the roof spanning along the direction of the ridges and valleys, so that each "truss" extends from end to end of the building and from ridge to valley of one "pitch" of the roof. Thus they comprise a structure rather analogous to a concrete shell roof. Prestressing is introduced into these trusses by cables following a parabolic (or polygonal) path, in the plane of the truss from near the ridge at each end, to near the valley at the centre of the truss. By prestressing such cables forces in opposition to the dead and live loads are introduced and the truss can be designed with greater economy. In one of these examples the roof was erected in a week from the prefabricated trusses. The weight of steel was 3·72 lb per square foot of covered area and its cost about 6s. per square foot, including the cost of prestressing the cables, which was, apparently, very small indeed. This construction, Mr. Samuely said, was the cheapest method of covering a space which he had experienced.

The discussion at the "Structurals" meeting was, of course, not without criticism of these novel structures. Corrosion protection, vulnerability to buckling, and even the venality of contractors in offsetting possible gains with rises in price, were amongst the points raised against them. Needless to say, such points were disputed, and on the whole the designs in prestressed steel were favourably received. For the prestressing process, although not so obviously advantageous as when applied to concrete, has many possible applications in structural engineering, with numerous materials, because of the way in which loads and stresses can be controlled and modified to suit the particular structural circumstances. Examples of such manipulation will be familiar to the student of prestressed concrete. Here we have more instances of them, with prestressed steel, a technique which offers good promise to structural engineers and which illustrates one aspect of the diverse possibilities behind the idea of "prestressing."

Obituary

ENGINEER REAR-ADMIRAL W. R. PARNALL

ENGINEERS and engineer officers of the Navy will have learned with regret of the death of Engineer Rear-Admiral W. R. Parnall, C.B., C.B.E., which occurred on Tuesday of last week, in his seventy-seventh year. Admiral Parnall, who was born on June 13, 1877, entered the Navy as probationer assistant engineer in 1897, after completing five years at college, and served in H.M. ships "Media," "Rodney" and "Thunderer." From 1900 to 1914 he carried out the duties of junior engineer officer in a number of naval ships, including the "St. George," "Prince of Wales" and "Gurkha," and also spent a year at the Admiralty, and three years, from 1906 to 1909, at the Royal Naval College, Dartmouth. He was promoted to commander in 1914 and served throughout the first world war with the Grand Fleet; he was chief engineer in the battleship "Erin" from 1914 to 1916, when he transferred to the "Queen Elizabeth" and was present at the battle of Jutland. After the war Admiral Parnall was chief engineer on board the cruiser "Southampton," the flagship of the South American station, and in 1921 he returned to England to join the staff of the engineer-in-chief. Two years later he became assistant engineer-in-chief and in 1927 he was appointed deputy engineer-in-chief, a post which he continued to hold until his retirement in 1930. He became associated with Parsons Marine Steam Turbine Company, Ltd., in 1935 and acted as that company's London representative until the time of his death, except from 1939 to 1944, when he returned to the engineering branch of the Admiralty. Rear-Admiral Parnall was made a Companion of the Bath in 1927 and was awarded the C.B.E. for his services during the second world war.

Literature

Budgetary Control and Standard Costs. By J. A. SCOTT. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, W.C.2. Price 18s.

THE advantages of budgetary control have been realised increasingly in recent years, and when it is possible to base the budget on standard costs, we have probably the best system to apply to engineering firms engaged in mass production or in a regular line of business. Mr. Scott clearly shows the value of a planned budget and deals in a systematic way with its evolution, the preparations of the necessary statistics, and the basic principles of costing, all being set out in a way that can easily be adapted to any form of business.

After an introductory section the book is divided into six main parts, the first being concerned with the budget itself, and its preparation in the respective spheres of sales, production, materials, labour, overhead and administrative expenses, and the cash budget ending with the profit and loss account and the balance sheet; the second part is devoted to standard costs, showing both their value

and application, and the accounting methods necessary for standard costs ; in the third part we return to the budget, being shown how the cost accounts are prepared, and used, as a result of presenting them in suitable report form to the management ; the fourth part deals with advanced budgeting, an important matter, based largely on good estimating, with past records if available ; the fifth part describes the financial control, how it is secured, and the value of graphs, and the necessary statistics ; finally, the sixth part is entitled " Action," demonstrating how the budget is applied, how to handle such contingencies as decline in orders or in output, defective planning and plant and research problems. There are four useful appendices dealing respectively and in some detail with costing methods, analysis and machine accounting, monthly accounts, and the fixing of standard times and rates. A bibliography of sixteen suitable books for further consultation on the subject completes a very useful volume.

The author rather disarms the critic when he says that " no rigid rule can be laid down as to the best basis " in setting up standards, and certainly if all cost accountants adopted a similar common-sense outlook there would be less friction between cost accounting and manufacture. Nevertheless, we feel Mr. Scott is rather severe in what he says about the more usual form of cost accounting, for whereas for mass production or the manufacture of similar articles standard costs are ideal, their application to works where no two jobs are alike would be at least debatable. While for firms manufacturing small arms ammunition standard costs proved most satisfactory, the same could not be said about their application to fighting vehicles. The idea of having a budget committee is most sound, the committee suggested having the general manager as chairman, and as members sales manager, works manager, accountant, and heads of departments, while this committee would have power to co-opt interested parties when their particular budgets came under review. This would all help to make everyone concerned realise that the value obtained from information should always be considered in the light of what it cost to get such information.

We agree that badly drafted budgets and standards badly applied will do more harm than good, but it is always well to realise that budgeting and determining standard costs rapidly improve if started on a right basis and conscientiously applied, but at the same time not expecting too much initially and understanding that it is not necessary to budget *in toto*. To those in the throes of installing a system the author's statement that " once installed a standard cost system usually involves much less routine work than the ordinary system " may prevent disappointment. Mr. Scott contends that " it is much more important to know what a product should cost than what it has cost," whereas we should rather say that the two should go together as of equal importance. Considerable attention is devoted to the question of preparing useful reports to assist the management, and we fully agree with Mr. Scott when he claims that " it is axiomatic such reports should state clearly what they intend to convey . . . and they should be prompt." Too often the value of the accounts produced is greatly minimised by the desire for unduly meticulous accuracy on the part of the cost office leading to a complete picture only being available long after the event. Attention is drawn to the necessity for having a regular routine for notifying the estimating department of faulty estimating, a most important consideration and one too often overlooked, for good estimating is largely attained in the light of experience, and there should be the closest co-operation between the costing and estimating departments, the cost office often being able to assist the estimator by showing the influence important potential orders would have on the factory expense.

In all works concerned with administrative or organising subjects, a " family tree " is a help in following out the relations between different functions, and we are glad to see that Mr. Scott has incorporated one, although we should welcome a few alterations. We cannot help feeling it would be a mistake to place estimating under the sales manager, or design under the works manager, it being preferable to have an engineering department embracing both these activities, and perhaps also being responsible to co-ordinate and follow up promises. Again, in large engineering factories, it is preferable to keep inspection distinct from the works management.

This book should prove a great help to those about to install budgetary control, or, indeed, have already set up such a system, while every manager who has never considered the subject would be well advised to ask himself whether, if he followed the lead set by Mr. Scott, his business might be run on more economical and efficient lines.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

TORRENTS OF THE EAST AND WEST LYN

SIR,—Mr. E. S. Crump's letter in your issue of February 5th drew attention to Mr. W. P. Thompson's letter published in your issue of November 6, 1953, which Mr. Dobbie and I had unfortunately missed. Both gentlemen made valuable contributions to the discussion on our Lynmouth paper[1] presented to the Institution of Civil Engineers, and a reply to their further remarks in your columns may be appropriate.

Mr. Crump's suggested amendment to Mr. Thompson's figures is doubtless correct. Whatever the numerical values, however, Mr. Thompson's main argument is of considerable interest. It would be difficult to prove that a steep natural river flowing over a bed of boulders cannot discharge its flood at velocities exceeding the critical, yet observations on natural mountain streams and on steep model channels with high bed roughnesses, e.g.[2] confirm that there is a limit of slope beyond which the mean velocity does not appreciably increase when the slope is further increased. This limit is certainly in the neighbourhood of critical flow, although the roughnesses of such channels are so large that a precise definition of mean width, depth and velocity is difficult.

In his discussion on the Lynmouth paper,[1] Mr. Crump (page 553) touches on the mechanism of energy dissipation by a series of oscillations of flow about the critical. Another mechanism has been mentioned by Professor C. M. White,[2] who refers to the effect in deep flow of secondary motion caused by large roughnesses. There is a basic similarity between the two mechanisms, but the action of secondary motion is not in any way connected with critical flow.

Mr. Thompson may be gratified to know that the concept of a limiting velocity in a rough natural stream was applied in the earlier stages of the emergency investigation into the Lynmouth flood. The estimate of peak flow at one section of the West Lyn was based on it,[3] although what appeared to be more precise estimates of roughness and flow were used in later work.

Another method of determining a flood peak, based on the consideration of the hydrostatic force and the momentum in the stream (the " total force " or " momentum flux," as opposed to its total energy or " total head "), was also applied to the West Lyn. At the right-angled corner in the West Lyn gorge described in detail in the Lynmouth paper,[1] a maximum water level could be deduced from marks on the site. This maximum water level corresponds to a hydrostatic force from which may be derived the coefficients in the equation relating the area of flow to the velocity of approach to the right-angled corner. Students of the phenomenon called " hydraulic jump " will be familiar with the fact that the maximum flow for a given hydrostatic force on the end wall is due to approach at critical depth and velocity. Mr. T. M. Chacinski and I independently used this method for estimating the maximum flow which would be consistent with the flood marks. Adding the refinement of correction factors allowing for the variation of velocity across the stream and for the extra width of end wall, we arrived at discharges of between 8000 and 9000 cusecs.

The hydraulic scale model of this stretch of the West Lyn[1] showed that flow in the channel approaching the right-angled corner was tranquil (or " sub-critical "), but that critical conditions occurred just at the inlet to the corner, justifying the calculation based on the " total force " concept. The peak flood flow in the West Lyn, in August, 1952, was shown by the model to have been approximately 8000 cusecs ; thus the velocities at the cross sections considered by Mr. Thompson and Mr. Crump were less than critical, as, indeed, had been shown in Mr. Dobbie's Table II and Mr. Crump's Table III of the Lynmouth paper.[1] This result serves as a warning against the indiscriminate use of the concept of a limiting critical velocity.

P. O. WOLF

Imperial College of Science and Technology,
South Kensington, S.W.7,
February 23rd.

THE IMPORTANCE OF IDENTIFICATION

SIR,—The importance of identification of engineering components is probably only fully understood by those faced with the problem of locating one specific item among a large number. While this particular problem is of restricted interest, there exists a similar type of problem which is of much wider interest and which concerns all those who read the technical press.

The problem is that of the identification of the real significance of a technical article as distinct, for example, from either a classification of its subject matter or an indication of the area over which the subject matter is spread. It is evident that in estimating the significance of the subject matter, some scale of values has to be established, since the range of articles in the technical press is necessarily wide. They extend from original contributions which widen the bounds of existing knowledge down to mere padding which says little or nothing at all that is of real significance.

This range of technical and descriptive articles is both inevitable and proper, and is readily accepted by readers of the technical press. What is less acceptable, however, is the time-consuming occupation of separating the wheat from the chaff, and although it may be argued that experience readily identifies the wheat, this is by no means always true, and ready identification is not always easy.

Technical articles which extend the bounds of existing knowledge are necessarily rare, and, like first-class hotels, might be suitably indicated. The range extends to articles which involve a new and useful presentation of existing know-

[1] " The Lynmouth Flood of August, 1952," by C. H. Dobbie and P. O. Wolf, Part III, *Proc. I.C.E.*, Vol. 2, No. 3, December, 1953.
[2] Report of the Committee on Fish-Passes," I.C.E., 1942.
[3] Hydrological Report by P. O. Wolf, Appendix 3 to Mr. C. H. Dobbie's Report to the Devon River Board on the Lynmouth Flood, October, 1952 (unpublished).

ledge, or, alternatively, the application of a new principle to a specific example of practical value. Further down the scale is the publication of other people's work rewritten in ways which might be useful to engineers and in some cases the republication of previously presented data, but by a new author and sometimes in a disguised form. There is the publication of factual information having no apparent utility and also the existence of articles appealing mainly to those having an amateur or general interest in a certain subject. There are, lastly, articles which assume to interpret previously published data, but without adding anything to it in the interpretation.

The field of locomotive engineering can be taken as an example. Since it has existed for over 100 years, it is unlikely that there can be technical articles in which the boundaries of existing knowledge will be extended, except perhaps in the case of gas turbine locomotives. It is possible, however, that existing knowledge can be presented in a new and useful way or new deductions drawn from existing and established facts. Articles of this kind have, indeed, appeared in THE ENGINEER.

It also happens that the field of locomotive engineering is a particularly fruitful one for exercising the art of interpretation. Examples of this art are seen in articles which interpret locomotive test results published by the British Transport Commission, but which add nothing new to the data contained in the original reports. More recently there has been an article in which a notable and original paper on locomotive testing has been rewritten and published, but again without adding anything to the original data. In reading such articles it may not immediately be apparent that the article only interprets existing data and it is precisely in such cases that time could be saved by indicating this fact explicitly in the heading of the article. A slogan for a well-known product could possibly be used, "Nothing has been added and nothing taken away." This type of article is all very well for enthusiasts who may like nothing better than a twice-told tale, but it certainly tends to time wasting in the case of those looking for new and significant data. To such, a system of ready identification of the real significance of published information would be doubly welcome.

R. SMITH

London, S.W.9,
February 19th.

[In so far as editors have consciences at all—we have heard doubts expressed upon the point!—ours remains clear. If, as we think he does, Mr. Smith refers in his final paragraph to articles by O. S. Nock on "Improving Locomotive Performance," which appeared in our issues of February 5th and 12th and which were based upon Mr. Ell's recent and very interesting paper before the Institution of Locomotive Engineers, he denies us credit which is our due. Short introductory summaries immediately below the headings of those articles established as prominently and explicitly as Mr. Smith could desire what were the natures of the articles which followed. If he did not wish to read a "twice-told tale" he had no need to. Moreover, Mr. Nock would be justifiably annoyed with us—he is a valued contributor whom we should deeply regret annoying—if we failed to point out that the articles contained a number of valuable comments of his own and quite a lot of additional information.

Upon Mr. Smith's more general argument, it may be added that he judges the value of an article too solely by its content. It is at least as much the duty of the technical press to inform as to instruct, to draw attention to new products, and to interesting pronouncements and events as to publish original contributions extending the bounds of knowledge. When a contributor "interprets," for example, a notable technical paper presented before an institution or the editor prepares a summary or an abstract, reviews a book or reports a speech (all examples of adding nothing), by no means all readers will have had the opportunity to read or hear the original. The majority, having no specialist interest in the subject, will be satisfied with what is presented; others will be informed whether or not it is worth their while to get hold of a copy of the original about which, it is very possible, they would never have heard if the article had not appeared. Thus there is not and cannot be an absolute scale of values applicable to articles appearing in the technical press. Their value is partly dependent upon the use each individual reader can make of them.—ED., THE E.]

FRENCH LOCOMOTIVE EXPERIENCES

SIR,—I feel that some comment is necessary on the articles appearing in THE ENGINEER by Mr. Edward H. Livesay on "French Locomotive Experiences." The impression which I have gained on reading the first two (in the issues dated February 19th and 26th) is that Mr. Livesay has an axe to grind, but that he is not at all sure with whom he should grind it. The expression of so much personal opinion in a supposedly factual article seems rather out of place, especially in a technical publication of such quality as THE ENGINEER.

He states that his task is to set out the facts, but surely these are very much embellished, to say nothing of their untidy presentation, punctuated by rather simple observations such as "What is the use of washing overalls—they only get dirty again." His first footnote on page 304 concerning goggles must be regarded as something of a waste of effort. Had the facts been more clearly and precisely presented, these articles would have been half the length and more easily readable. I suggest that Mr. Livesay consider these points in the preparation of his future articles, because I submit that the average reader of the technical periodical is not really interested in personal interjections of the type encountered here.

Finally, I must cross swords with Mr. Livesay in his praise of the fireman on the run on the English side of the Channel. Constantly to have the safety valve lifting is surely a sign of gross over-firing with consequently high fuel consumption.

B. J. CONNOLLY

Stockton-on-Tees,
March 4th.

LOCOMOTIVE TESTS

SIR,—There is a sinister suggestion of bureaucracy in the statement that locomotive testing is now so efficient that it enables optimum schedules to be prepared—from the point of view of the locomotive.

Those who administer a nationalised industry should regard themselves as trustees for the nation. Their first, and most important, duty is to prepare schedules which will meet the convenience and needs of the community; when that has been accomplished they can set about designing locomotives to do the work. They must not begin at the wrong end.

W. B. THOMPSON

London, S.W.1,
February 23rd.

[Surely our correspondent is quite unduly suspicious? It is obvious that if locomotive testing becomes more precise, more can be learned about any given locomotive's performance, and therefore better use be made of that locomotive. It is an entirely distinct question whether the railways are preparing schedules "which will meet the convenience and needs of the community" and "designing locomotives to do the work." There can be more than one view about that question; but only agreement, surely, upon the desirability of drawing up optimum schedules for any locomotive already on the rails.—ED., THE E.]

INDUSTRIAL HYGIENE ENGINEERING

SIR,—My article on "Industrial Hygiene Engineering," which you published in your issue of December 18th, contained a reference to "some thirty factories" under the Industrial Health Service of the Nuffield Foundation at Slough. This should have read 160 factories employing 15,500 people.

I shall be grateful if you can see your way to publish this correction.

T. C. ANGUS

London, W.C.1,
February 24th.

Institution of Mechanical Engineers' Summer Meeting

THE summer meeting of the Institution of Mechanical Engineers is to be held in the Netherlands this year from Tuesday, June 15th, to Friday, June 18th.

On the first day of the meeting the members will be officially welcomed by the Burgomaster of the Hague, Mr. F. M. Schokking, and the president of the Koninklijk Institut van Ingenieurs, Dr. J. A. Ringers, and an address, "The Industrial Netherlands," will be delivered by Mr. F. Q. den Hollander, the president of the Netherlands Railways. Afternoon visits will be paid to one of the following establishments:—Unilever N.V., Wilson-Fijenoord Shipyards, Allan and Co., or Nederlandsche Kabelfabriek. In the evening a reception is being held in the old town hall of the Hague, by invitation of the Minister of Education, Arts and Sciences, and the Municipal Board of the Hague.

The programme for the next day includes a morning meeting of the Automobile Division of the Institution at the Royal Dutch Shell works at Pernis, in the course of which Professor J. J. Broeze will read a paper, "Automobile and Petroleum: Past, Present and Future." Alternatively members can visit the engineering workshops and laboratories of the Technological University at Delft; or the central workshops of the Netherlands Railways at Tilburg; or the repair workshops of the K.L.M. at Schiphol Airport and the works of Werkspoor, Ltd. That evening the Institution dinner will be held in the Hotel Kurhaus, Scheveningen.

A number of alternative visits have been arranged for Thursday to Philips Electrical Industries, Ltd., at Eindhoven; Van Doorne's Automobile Factories; Koninklijke Maschinenfabriek Gebr. Stork and Co., Ltd.; and G. Dikkers and Co., Ltd., at Hengelo; or the Royal Netherlands Blastfurnaces and Steelworks, Ltd., at Beverwijk.

Two alternative whole-day fixtures have been arranged for the Friday. One will include visits to the surface plants of the State Mine Maurits, and the other a motor coach tour through the North-East Polder and a steamboat trip along the works in progress on the East Polder. At the end of the day the two parties will assemble at Scheveningen, where it is hoped to arrange an informal farewell function.

Books Received

Protective Atmospheres. By A. G. Hotchkiss and H. M. Webber. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 56s.

Radio Receiver Design. Second edition. Part I. By K. R. Sturley. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 56s.

The Mechanism of Economic Systems. By A. Tustin. London: William Heineman, Ltd., 99, Great Russell Street, W.C.1. Price 25s.

Mechanical World Year Book, 1954. Published in Manchester by Emmott and Co., Ltd., 31, King Street West, Manchester, 3. Price 3s. 6d.

Gears.—Third edition. By H. E. Merritt. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 60s.

Axialkompressoren und Radialkompressoren. By B. Eckert. Germany: Springer-Verlag, Reichpietschufer 20, Berlin, W.35. Price Dmk.73·50.

Safety in the Air

By AIR COMMODORE SIR VERNON BROWN, C.B., O.B.E. (Retd.)*

The following abstracts are from the second of a series of three Cantor Lectures on "Safety in Transport," presented to the Royal Society of Arts. It was read before the Society in London, on Monday, March 1st., and in it the author discusses eight of the fundamental qualities necessary in a modern aircraft. Included in the abstracts below are the author's comments on adequate arrangements for survival in low-speed crashes and ditchings and an outline is given of some of the problems of accident investigations.

Crashworthiness.—I do not know who coined this word, but I think it is a good one. Broadly speaking, it refers to the provision of protection of an aircraft's occupants in a crash. I have already said that the proportion of accidents due to airworthiness defects is small ; I believe that, short of trying to offer protection in accidents of the collisions and flying into mountains kind, there are probably no drastic foreseeable improvements at present.

But a lot can still be done to save people from death or injury in the lesser kind of accident, by which I mean over and under-shooting, belly landing, ditching and the low-speed survivable kind of crash—perhaps accompanied by fire. Please do not misunderstand me. A great deal has already been done in such respects and crashworthiness problems are being constantly reviewed. For example, means of preventing fires, and of detecting and extinguishing them if they unfortunately do occur, are the subject of continuous research and development. But one must not be blind to the fact that a crash which involves the destruction on impact of an aircraft's fuel tanks and releases hundreds or even thousands of gallons of highly inflammable fuel, some of which may be sprayed on to red hot exhausts or jet tail pipes, is a very difficult problem to overcome. But a major fire can only occur if a large quantity of inflammable fuel is released and this can hardly happen unless the fuel tank or tanks are broken. The evaluation of integral and bag tanks is a matter for experts, and I can do no more than suggest that whatever kind of tank is used it should be capable of withstanding high impact loads, should not be placed

Fig. 1—Hailstone Damage to Aircraft

in an unnecessarily vulnerable position, and ought to be as far away as possible from the known sources of ignition. Moreover, it should not have an array of pipelines, pumps and excrescences on the underside, where crash impact is most likely to cause damage or total disruption.

Next, I must mention the much-discussed controversial question of backward facing seats. There is ample evidence that in crash landings head injuries are the most frequent causes of death or serious injury. Now the human frame can stand a lot of *g*, and I would like to think that if, say, 20 *g* is sustained, the structure of the aeroplane and the safety factor of the seats should be able to withstand this, because I am pretty sure most people can, if only they are adequately protected.

Obviously the extent and nature of injury must depend on whether the seat and safety belt remain intact and the extent of damage to the aircraft itself. In a straight crash one's body will be projected into whatever lies ahead and unless seat and belt hold serious injury may result. Even if they do not give way, the head and abdomen may suffer. According to Mr. de Haven, of the Crash Injury Research Medical College at Cornell University, people can survive 40 *g* with only a belt. Nevertheless, the provision of an adequate belt or harness for small children or for people of abnormal shapes and

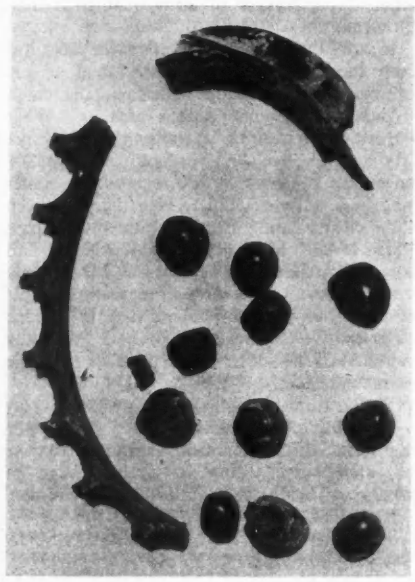


Fig. 2—Ball Race of Crashed Aircraft

sizes raises a lot of difficult problems, and I am certain that if seats were constructed to withstand at least 20 *g*, and if, in addition, they faced backwards and were provided with adequate head, back and leg protection, the mortality cum injury figure would in the case of survivable accidents be reduced to an almost negligible quantity. I feel very strongly about this and recommend anyone interested in the subject to read Mr. Hardingham's short paper, "Can Chances of Survival be Increased ?" which was printed in the R.Ae.S. *Journal* in July, 1948.

On January 20th this year a Royal Air Force "Valetta" crashed shortly after take-off from a Service Station in the West Country. Of the five crew members one was killed and three seriously injured. But of the eight passengers, who included two children age four and five respectively, five were unhurt and three suffered minor injuries. They were all sitting in backward facing seats.

If it should be necessary to alight in the sea, it is important that an aircraft should float for sufficient time to allow for evacuation of its occupants into boats or dinghies which will have a good chance of survival. Therefore the aircraft should be a reasonably good "ditcher," the exits should be adequate and evacuation drill should be explained to everyone and simple to carry out. Life jackets must be easy to put on and inflate, and the life-saving craft should be of a kind to give protection and some degree of warmth and, of course, be equipped with food, water and medical supplies, radio and navigational aids.

Some time ago the Air Registration Board carried out tests to determine the effect of briefing as to the way to put on and inflate life-saving jackets. I am told that the results showed that the time factor alone might mean just the difference between saving and losing lives and produced ample evidence to support my assertion that, given the proper equipment and with good team work, there should not normally be any drownings, but that passengers must be told where their life jackets are stowed and shown how to put them on. They should not be left to find out for themselves, after an emergency has already arisen.

I submit it is nonsense to say that reference to such matters frightens people. One goes through all this in a ship, so why not in an aeroplane, where the need is so much greater and where speed of action is so important ? I have asked many people for their reactions to a talk on, or demonstration of, this kind of life-saving drill, and have never yet been told that it made them nervous. On the contrary, men have assured me that it gave them confidence.

Another important item under this heading is emergency exits, and this is, of course, just as important for ground as for sea evacuation. An exit is of no use if it cannot easily be opened ; if it is too small for a passenger of abnormal build to use, and if on getting out of it one has to drop 20ft—or even 10ft—on to hard ground or into the sea with a good chance of breaking a limb in the former or being lost in the latter case. Moreover, exits must be so constructed that they will not jam owing to fueselage distortion. I suggest, too, that it really is time that a standard method of opening were accepted. After all, it is important that any passenger shall be able to open the door in an emergency and perhaps in the dark should no member of the crew be available.

Accident Investigation

Without knowing why an accident or incident occurs no steps can be taken to prevent a recurrence. Therefore there should be a careful

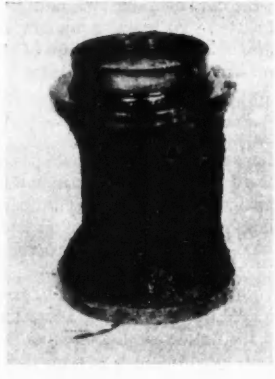


Fig. 3—Oil Pressure Filter from No. 3 Engine, Showing Carbon-Choked and Collapsed State

investigation of every untoward event. It was this accepted view that, as far back as 1920, led to the establishment in this country of an Accident Investigation Branch. It was decided that its head should be directly responsible to nobody below the Minister concerned with civil aviation in order that he might be able to speak without fear or favour. Apart from any inquiries, such an organisation may carry out for, or advice it may be asked to give to, the Fighting Services, its main function is to investigate civil flying accidents in order to make it possible for the Minister to carry out his responsibilities to Parliament and so to the public.

Compared with a ship or a railway train, an aeroplane is a vehicle of flimsy construction, which of necessity contains a lot of inflammable substances, in particular, fuel, lubricating and hydraulic oils. It has many instruments and

* Late Chief Inspector of Accidents, Ministry of Civil Aviation.

devices connected with electrics, hydraulics, pneumatics, and the like.

Weather.—An aircraft may encounter storms, sometimes accompanied by turbulence of a kind to give rise to severe buffeting. It may also meet with conditions of rain, hail, icing, snow or fog. Fig. 1† shows the damage that can be caused by hailstones. It may also be struck by lightning. [The small holes which are blown in an extremity such as a wing tip or, as in a case, an aileron shroud, and the way in which some of the metal is fused were shown on a slide.] This gives a rather frightening picture, but one cannot ignore weather hazards when flight safety is being considered. Let me assure you at once that, although accidents have been caused by loss of control in some of the conditions I have just mentioned, I cannot honestly say I know of a single fatal lightning strike. Glazed ice is rare and early warning of such phenomena is usually given. If fog is such that visibility is reduced to what is below the operator's minima, a diversion is always offered or advice given to a pilot to return to base before his " point of no return " is reached.

Material.—It might be thought that in such a case [high-speed crash] examination of the wreckage cannot possibly produce any evidence of value. In fact, careful and systematic examination frequently yields remarkable results. [A slide showed a hole from which the bits and pieces of an aeroplane were dug from a depth of well over 35ft.] In Fig. 2‡ can be seen the overheated ball race which caused engine failure and subsequent fire resulting in loss of control and the final crash.

Now, as most of you know, during the failure of a metal structure the material is deformed before it yields and when it does finally yield evidence of that deformation usually remains. [The author then illustrated a typical tensile failure of metal, and a fatigue failure in a propeller blade showing quite clearly how the arcs had built up from the seat of origin. In another slide the gap between the rivet and hole edge could be seen.] The direction of failure of rivets is important and it should thus be possible to determine the direction of movement of the adjacent structure.

It has to be learnt by experience what certain marks on the aircraft surfaces indicate. [Slides indicated the damage which can be caused by a bird striking the leading edge of a wing, and the heavy damage caused to the leading edge of the tailplane as the result of its being struck by a dinghy bottle after the inadvertent release of the life-saving craft.]

If an aeroplane wing breaks up in the air—a very rare occurrence in civil aviation, I am glad to say—it is important to know the direction of failure. [A slide was shown indicating how this may be determined.] This photograph shows how smear marks can give evidence of a primary or secondary failure. The mark which extends across both portions of the aileron shows that it was caused when the two surfaces were still mated together and that the surface had been struck by something before the break occurred.

From these pictures you will understand the importance of careful wreckage examination—not only on the spot, but, if necessary, later under laboratory conditions. That is why the Inspectorate of Aircraft Accidents is so desperately keen that the wreckage of a crashed aeroplane should be left intact until an opportunity has been afforded for expert examination. The removal of pieces of wreckage may well ruin all chances of successfully finding the cause of an accident.

Fig. 4‡ is a good illustration of what I am trying to emphasise. This piece of white plastic material was a portion of the nose of an experimental aircraft which broke up in the air during test. You will see embedded in it a small piece of wood. This was only about 4in long and was discovered to be a piece of one of the blades of the wooden propeller. The fact that it was embedded in the nose was a strong indication that the propeller had failed before the airframe, and this was subsequently proved to have been the case. This piece of material was found more than 3 miles behind the main wreckage and it was fortunate that the finder marked the spot and covered the piece over with leaves as a precaution. Sometimes people find parts like this and throw them away, or, what is worse still, take them home as souvenirs.

The next slide is another photograph illustrating how careful examination of wreckage can produce valuable evidence. It shows the remains of a control column and the fact that the aileron locking pin was discovered fired into its hole in the steel rod when all the outer casing had been destroyed by fire showed that the pilot had taken off with his ailerons locked.

Accidents attributable to bad maintenance are very rare. There have, of course, been some due to this, but the majority have fallen into the private owner class. Bad maintenance caused an accident which unfortunately resulted in the deaths of thirteen people. This was not an English aircraft. Fig. 3‡ shows the condition of

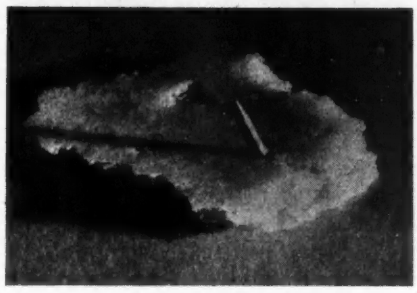


Fig. 4—Propeller Splinter Through Plastic Nose of Aircraft

the oil pressure filter of one of the engines of this four-engined aircraft. It was so choked up with sludge that it had already begun to collapse.

The Passing of information Among Government Departments, Designers, Manufacturers and Operators.—This is very important. I divide it into two categories : (1) the reporting of every accident and incident, and the passing on of the report even though it may seem to be only of local interest ; and (2) the dissemination of technical information.

In the latter category I quote the following by the head of an airline's department of service troubles and research :—

" Also occasionally one meets a reluctance on the part of the designer to change a construction which shows malfunctions, even in cases where a solution is easy. I could produce here many examples, but I will restrict myself to one very

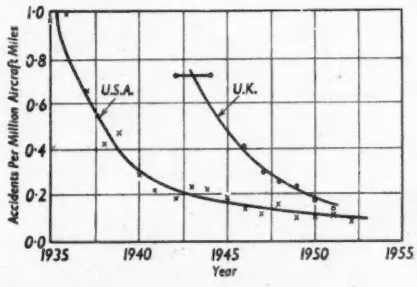


Fig. 5—Accident Statistics

obvious case. You may know that in order to climb to very great altitudes it is necessary to have the engine provided with a two-speed impeller or blower. During operation this blower has to be changed from low to high by means of a clutch system. Originally this clutch was operated by a cable connection and never gave any trouble. Then this device was changed to an actuator, which resulted in endless trouble. For years we have been advocating the return to the cable, which was light and reliable. Now, after five years of trouble, the factor is returning to a reliable cable in its newest type."

That illustrates a perhaps natural disinclination on the part of a designer to change a construction which is not entirely satisfactory. But it is even more important that some really vital piece of information obtained by one organisation should be made available generally if safety is concerned. It is, of course, easy to understand reticence on the part of a designer or operator where commercial rivalry is concerned, but if people's lives are in danger to keep it " under the hat " for purely personal reasons could be an almost criminal act.

Statistics.—Another important aid to safety is the compilation and analysis of statistics. But statistics must be accurate and must not be based on numbers which are too small to be realistic. Statistics can be very helpful technically, but may be a danger in the hands of those who do not understand them.

Generally, numbers of accidents or numbers of fatalities are related to revenue passenger miles or to revenue aircraft miles. Thus one learns that in the United Kingdom in 1950 the passenger miles flown per passenger killed were 16,198,500, which means that 23,600 miles were flown per passenger killed. If you prefer, you can have it that there is 0·045 fatal accident per 1,000,000 aircraft miles or that the passengers killed per 100,000,000 passenger miles were 6·2. If you like, it can be shown that the stage flights per fatal accident numbered 61,300. For my part, I think the most realistic picture is that 22,395,000 aircraft miles were flown per fatal accident.

According to Mr. Masefield, of British European Airways, " Anyone can be almost 100 per cent safe during the normal span of life—except for acts of God, such as earthquake, lightning, tempest, pestilence, famine and flood—so long as he remains entirely static and earth-bound. Equally obviously an element—but only an element—of risk is introduced when he takes the air." I believe when Mr. Masefield used these words he had in mind that it was said that in the United States in 1947 more people were kicked to death by donkeys than were killed in air transport.

I have tried to obtain some statistical evidence as to which is the safest form of transport, but there are so many variables that no comparison seems possible. As to whether it is safer to travel by road, sea, rail or air I can only say your guess is as good as mine. Anyhow, in respect of air travel both in the States as well as in the United Kingdom, Fig. 5 gives a picture which I think will give you confidence. It shows the accident rate trend, and I am grateful to Mr. Tye, of the Air Registration Board, for allowing me to make use of it. You will see that our American friends had about seven years' start of us and that we have taken about ten years to catch up with them.

Publicity.—In so far as publicity may serve to keep designers, manufacturers and operators on their toes it can serve a useful purpose, but compared with other forms of transport the aeroplane does often seem to be at a disadvantage. A distorted picture of airline safety is likely to shake public confidence, and I do suggest that the too well-illustrated front page news of an aircraft accident sometimes results in a disservice to aviation generally and to British civil aviation in particular.

† British European Airways photograph.

‡ Crown copyright reserved.

Xenon-Filled Valve Rectifiers

Two inert gas-filled rectifiers, known as types " RR3-250/3B28 " and " RR3-1250/4B32," have been introduced by Mullard, Ltd., Century House, Shaftesbury Avenue, W.C.2. They are for use in the high-tension supplies of radio transmitters and similar equipment, and are designed to be mounted in any position and operate over a wide ambient temperature range (about −55 deg. Cent. to +75 deg. Cent.). The heating time of the two valves—ten and thirty seconds respectively—is shorter than that of mercury vapour rectifiers. The two new valves are direct replacements of the American types of valve " 3B28 " and " 4B32."

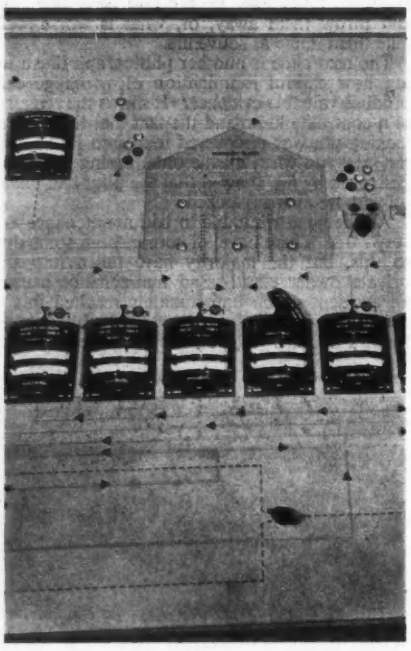
In a single-phase full-wave circuit a pair of " RR3-250's " are capable of an output of 0·5A at 3200V. Two " RR3-1250's " under the same conditions, have full-load ratings of 3200V at 2·5A. The " RR3-250 " has a medium four-pin bayonet base, and the " RR3-1250 " a B4F base. Filament ratings are 2·5V at 5A and 5V, 7·1A respectively. The " RR3-250/3B28 " can be supplied to specification CV1835 and the " RR3-1250/4B32 " to specification CV2518.

Electronic Control of Crude Oil Distillation

On a recent visit to Evershed and Vignoles, Ltd., Acton Lane, Chiswick, London, W.4, we saw one of two control desks which this company is making for the Aden refinery of the Anglo-Iranian Oil Company, Ltd. Each desk is designed to control a crude distillation unit of 60,000 barrels per stream day. The desks are the first of their kind to incorporate electrical instrumentation and electronic process controllers throughout.

Briefly the system of control is that the readings of measuring elements (such as pressure level and flow meters) on the plant are converted into direct current of 0 to 30mA and transmitted over multi-core cables to the indicators, recorders, and controllers mounted in the desk. The controllers* are electronically operated and are designed to compare the measured value (of pressure, level, flow, &c.) with the desired value. The difference, or error signal, is transmitted by multi-core cables to the appropriate electro-pneumatically operated valve positioner on the distillation unit and the positioner is restored to the desired value; thus, the error having been eliminated, the system is balanced. The controllers are three-term equipments incorporating proportional, integral and derivative action.

Physically each controller is a self-contained plug-in unit enclosed in a flameproof case. For convenience of servicing, these controller units are nested in cubicles in the side wings of the desk. The indicating part (known as a "Mini-Plaque") of each controller is mounted on the sloping face of the desk so as to form part of the mimic diagram of the plant, as shown by the accompanying illustrations. Two scales can be seen on each controller; one is for indicating the actual and desired values and the other is for manual control. Above these scales there is a removable plate which gives access to the proportional, integral and derivative adjustments.

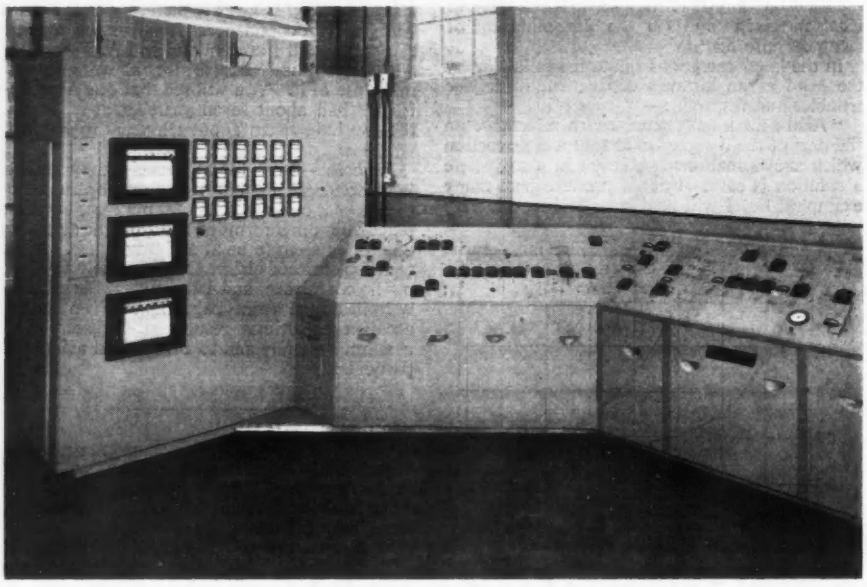


Part of the Control Desk Showing a Group of "Mini-Plaque" Controllers

In all there are some forty controllers for regulating the process conditions at various points in the distillation plant.

Transmitters are also installed to give an indication in the control room of the specific gravity of various products from the plant. At selected points in the process five of the measured values are connected to audible alarms to give warning of any excess deviation from the desired values. Potentiometric temperature recorders are mounted in each of the wing panels, together with a number of miniature recorders, as illustrated. These miniature recorders have 2in wide scales but the effective sensitivity can be increased by a range-suppression device. Summation of the various products from the plant is effected by electrical integrators mounted in the wing panels.

The desks are arranged for shipment in five sections: the three central sections form the desk proper and on each flank there is a wing section, one of which is illustrated. To facilitate assembly on site and subsequent maintenance, the desk sections are provided with quick release terminals. Each desk will be installed in an air-conditioned control room overlooking the distillation unit and from it the operator will be able to regulate the flow, pressure, level and temperature of the various oil streams passing through the plant.



Left-Hand Wing of Control Desk for the Aden Refinery

* "The Application of Electronic Process Control to Oil Refineries," by W. T. Marchment. Eighth National Conference of the Instrument Society of America, September, 1953.

Vacuum Plant Factory

Some thirty-five years ago the firm of W. Edwards and Co. (London), Ltd., was established by Mr. F. D. Edwards, and up till 1939 it acted mainly as agents for imported vacuum pumps and equipment. At the outbreak of the war, however, the demand for vacuum equipment became so great that the firm decided to extend its then limited manufacturing capacity and specialise in the production of pumps and equipment to its own designs. In the years following the war, the demand for equipment continued unabated, and this demand, coupled with a steady increase in the range of plant made, eventually exceeded the productive capacity of the works. For this reason, the firm decided to lay down and equip a new works at Manor Royal, Crawley, Sussex, which was officially opened last week by Sir Ben Lockspeiser.

The new factory at Crawley covers an area of about 100,000 square feet, of which three-quarters is given over to manufacture, development and research work on high-vacuum plant, instruments and accessories. Actual production is carried out in a large well-equipped machine shop, and a sheet metal and welding department, with adjoining assembly areas, each of which has an associated testing section. A development department is served by its own machining section, and its work is carried out in close contact with the research laboratories.

Research investigations are continuously in progress on pumps and pumping problems, instruments, vacuum metallurgy, freeze drying, &c., and as far as possible in laying out the new factory the laboratories have been kept close to one another, as in practice the work of one section has often been found to influence that of others. In these laboratories no part of the floor area is more than 20ft from a grid carrying power, gas, cooling water and compressed air supplies.

Crop-Spraying Machines

A paper on the development of crop-spraying machines in this country and overseas was presented by Mr. E. R. Hoare at a meeting of the Institution of British Agricultural Engineers, which was held in London on Tuesday last. In the course of the paper, Mr. Hoare emphasised that the foremost function of the spraying machine was to spray a fluid, but he pointed out that the greater part of the problem was concerned with the quantities of fluid to be sprayed and the form of spray. The size and number of droplets were the measurable criteria through which engineers could define and biologists measure the effects of spraying operations on the crops. As well as discussing these factors, the paper dealt with the formation of droplets from a mass of fluid, and with their measurement. Setting out some "practical methods" for the consideration of engineers, Mr. Hoare said that, by common usage and by experiment, the application of large volumes of material ranging from 60 to 400 gallons an acre had been applied by the use of nozzles of the swirl or flat design. The spray, it was explained, resulted primarily from the breakdown of a film of liquid after the film had been extended in the free space after coming through the nozzle. The very method of its formation resulted in an uneven droplet size distribution, and if the droplets were large enough they contained sufficient kinetic energy to be projected and carried to the area of deposition. As the volume of application became less so the orifice diameter needed to become smaller, and there came a time, Mr. Hoare said, when the nozzle diameter was so small that it was easily blocked and also, due to the high velocity, it was difficult to maintain a constant orifice size because wear caused a proportionately large error on a small orifice. When a low volume spray was required small droplets must be used and in consequence a small orifice to the nozzle. This, in turn, decreased the throughput of a nozzle and more nozzles must be used resulting in a large maintenance problem.

Engineering Research and Design Building

A recent visit to the Heaton works of C. A. Parsons and Co., Ltd., gave us the opportunity of seeing the company's new research and design building. Some of the interesting ideas embodied in this building, including the heating and lighting systems, are described and illustrated here, to provide a background for a brief reference to the sort of work that is done in the building.

TOWARDS the end of the second world war, when it became clear that the future demand for power plant would exceed the existing manufacturing capacity, the firm of C. A. Parsons and Co., Ltd., was faced with two urgent requirements. The first need, which applied equally to other makers of generating plant, was for improved and greatly extended workshop facilities. In the post-war programme for the development of the Heaton works priority was, therefore, given to increased output : a new alternator shop and a steam pipe bending works were built and the transformer and turbine shops were largely rebuilt.

It was not until these improved workshop facilities had been provided that the company was able to turn its attention to the second, and almost equally pressing need—the provision of a new building for the research, technical and administrative staffs. Hitherto, the majority of these departments had been housed mainly in a three-storey building, two floors of which formed the original office building ; the remainder, including important groups of the research staff, were accommodated in various temporary buildings dispersed throughout the works. The need for the new centralised design and research building became more acute as time went on and the increased turnover in the shops made increasing demands on drawing-offices which had no room for expansion.

In 1950, the decision was made to proceed with the final preparation of schemes for a new building. From the limited number of available sites the one chosen was in the right angle formed by Shields Road and Depot Road at the south-west corner of the works. This site was partly occupied by the original No. 1 Machine Shop, built by Sir Charles Parsons when he started Heaton works in 1889. An alternative light machine shop had already been provided, largely to replace this shop, and what work was still carried on in the original shop was transferred to new premises at the east end of the works, made available by the removal of the blade shop to Heaton South. The rest of the site was occupied by other original shops which were at that time being used as temporary technical offices. Further temporary quarters had to be found for the occupants of these premises before site clearance could be started. At the south end of the site, facing Shields Road, stood the existing office building of three stories fully occupied by various staffs. This building was 27ft 6in wide from the Shields Road building line at this point, and since it was fully occupied the plans provided that the south frontage of the new building should be behind the original. Thus when the new building had been completed and the offices in front of it had been demolished, the space left vacant provided for a private drive in, and an island car park separated from the Shields Road by a low parapet wall, as illustrated on this page.

It will be seen from this illustration that the building is L-shaped in plan. The shorter wing, which forms the south frontage and includes the main entrance, is 183ft long, the frontage being set back 40ft from the building line in the Shields Road. The longer wing of the building measures 311ft and it faces the Depot Road on the west. A view of the opposite side of the Depot Road wing, taken from the Shields Road wing, is reproduced on Plate 3.

Two major considerations determined the layout and design of the building : the first was to eliminate the need for unnecessary movement on the part of members of the staff in the performance of their duties ; the second was the provision of satisfactory working conditions and particularly of ample lighting, making the best use of daylight, amplified, as required, by artificial lighting. It will be seen from the subsequent description of the building that these requirements proved to be complementary rather than conflicting.

Research laboratories and technical offices occupy almost the whole of the Depot Road wing, which is divided into six floors, including the ground floor. As can be seen from the accompanying illustrations, each floor is, as far as possible, open and unobstructed. Internal corridors are reduced to a minimum ; similarly, departments on the same floor are not separated except when necessary, and then only by the use of wood and glass partitions (Plate 4). Application of this principle combines economy of space and movement and makes the best use of available daylight. The width between the outer walls is 62ft and the floor-to-ceiling height is 12ft 6in. On each floor both sides of the building consist mainly of windows about 9ft high and separated only by the structural columns and mullions.

The south wing, which faces the Shields Road, is occupied mainly by design and administrative floors and canteen services. Here the offices are smaller and are separated by a half-glazed central corridor. Daylight being less important than in the other wing, the floor-to-ceiling height here is only 9ft 3in and this reduction provides height for a seventh floor (as can be seen from the illustration above), the overall height of the south wing being approximately the same as that of the west wing.

Both wings are joined at the south-west corner by a rectangular hall which is common to each floor. On each floor this hall gives access to the continuously moving "paternoster" lift installations and the main stairway and toilet accommodation. The differences in floor levels caused by the differences between the floor heights on the two wings are made good wherever possible by a sloping ramp from the hall rather than by steps. There are secondary staircases and lifts at the north end of the Depot Road wing and the east end of the Shields Road wing.

From the structural point of view, the building itself is of conventional steel-framed construction. It was the subject of an article in the *Heaton Works Journal*, Vol. 6, No. 37, 1953, and we do not propose to describe it in detail here. Our object rather is to refer to those aspects of the building that are unconventional and to indicate some of the activities for which the building was designed.

Because of the local atmospheric conditions the exposed surfaces of the building elevations were made wherever possible of hard impervious material which could easily be washed clean. A combination of precast terrazzo polished granite and pressed facing bricks was, therefore, chosen for the outside finish, apart from the glazed portion which accounts for about 50 per cent of the surface area. Paintwork is virtually eliminated from the outside surface. Window cleaning, which forms an important item of maintenance in this building, is to be simplified by the use of a commercial design of mobile fire escape adapted with working platforms at levels to suit the various floors.

On the Shields Road frontage emphasis is given to the vertical columns by setting back the walls behind the column casings, the end columns being further accentuated by providing additional depth. The heavy horizontal coping at the roof and the broad sill below the ground floor windows help to give the visual impression of a frame. To achieve a contrasting effect with the Depot Road elevation continuous horizontal bands of brickwork are shown between the windows so that the columns are exposed only where they separate the windows.

On the Shields Road wing the walls are of 9in brickwork faced with 1½in thick slabs of polished " Inver Gray " granite, which is easily washable. The other wing is enclosed by 11in brick cavity walls, the outer leaf being of locally made red facing bricks.

Piled foundations were used for the building after trial bore-holes had shown the presence of large deposits of soft loamy soil at depths up to 35ft over much of the site. Each stanchion foundation rests on 400 cast-in-situ piles, between 15in and 19in diameter and 10ft and 40ft long.

Research and Design Building as Seen from the Shields Road

The reinforced concrete pile caps, which form the bases for the stanchions, carry a load of 475 tons in some cases. These foundations are either immediately below the basement floor, or where no basement exists, 12in below the ground floor and are all connected with reinforced concrete beams laid *in situ*. The whole of the basement is a heavily reinforced concrete tank lined on the inside and floor with 1in thick asphalt ; inside this tanking a second reinforced concrete floor is laid and 9in internal brick walls built. Because of the water pressure encountered during piping operations and since, dummy bore-holes have been left below the basement ; they constantly discharge water which is collected into a drainage system immediately below floor level, relieving pressure on the basement walls.

Throughout the building the structural floors are of reinforced concrete of inverted trough construction, approximately 70 per cent of the floors being laid *in situ* on sheet steel formers and the remainder being precast. Above this structural floor is laid, first, a fine aggregate concrete 2¼in thick, and then a 1in sand and cement screed, laid level to receive the various floor finishes which are generally of cork.

Some of the floors in machine rooms and certain laboratories have been suitably strengthened, both in the supporting steelwork and in the reinforced concrete work to take greater loadings than normal. The roof is of similar construction to the floors, except that, for thermal insulation purposes, it is completely covered with a 2in thick cork mat and then with 1in natural rock asphalt into which Derbyshire white fluorspar chippings are rolled.

An interesting point about the building fabric is that all the outside windows are made up of double-glazed, hermetically sealed units. Each unit consists of two panes of polished plate glass, separated by about ¼in by a metal spacer. Before this unit is sealed with a mastic compound the air between the two glass panes is dehydrated. This construction provides good thermal and sound insulation and prevents condensation.

To avoid the use of window frames, as far as possible, most of the glass window units are fixed direct into the building stonework. Fixing is done from inside ; the panes rest against rubber blocks and are bedded and pointed in non-setting mastic, being held in position by a specially designed snap-on aluminium beading fitted on the inside of the window.

Forced ventilation is provided throughout the building as described below, but it was felt that some concession should be made to convention by providing some window openings for use in very hot weather. Accordingly, as can be seen from some of the photographs reproduced here, the lower section of all window openings consist of anodised aluminium frames. The central sash of this frame is hinged at the bottom and opens as a hopper with friction-operated collapsible side cheeks. These frames, too, were designed to take the double glazing, fixed with snap-on beading.

The lift installation calls for comment mainly because of the use of "paternoster" lifts which are rarely seen in Britain, although they have, for many years, been widely used on the Continent. There are three sets of continuously moving "paternoster" lifts in the main hall. Each of the three lifts consists of fourteen open-fronted cars and each car can carry two persons. Each lift travels in a single brick shaft which is separated in the centre by vertical guides to form an "up" and a "down" shaft. The cars are suspended at diagonally opposite corners on two endless chain drives (operated by constant speed electric motors in the plant room above), and they move continuously along the "up" and "down" shafts at a speed of about 80ft per minute. When each car on the chain reaches the top of the "up" shaft it is transferred horizontally to the "down" shaft, at the bottom of which it is again moved horizontally to the "up" shaft and then completes its cycle of movement.

Lighting, Heating and Ventilating

The lighting, heating and ventilating are so closely related one to another and to the design of the building itself that they may conveniently be considered together. The ceilings themselves play a major part in the provision of these services. On each floor the whole of the ceiling, apart from the air-circulating louvres is built up of inverted trough-shaped, anodised aluminium reflectors which are specially designed for a three-fold function.

First, they reflect the light produced by continuous lengths of cold-cathode fluorescent tubes arranged side by side, so that almost the whole ceiling is a source of light. Secondly, the reflectors have specially formed recesses to accommodate water pipes of square cross section, and they therefore radiate heat as well as reflect light, over the entire ceiling area. Finally, the reflectors are perforated to allow sound to be absorbed in the sound-and-heat-insulating material which forms a backing for the whole of the reflecting surface.

Various examples of this form of lighting are illustrated herewith. In the Depot Road wing, for instance, "Intermediate White" cold-cathode 9ft 6in tubes are arranged in groups of thirty-six, each group forming an illuminated panel 27ft by 16ft. Such an installation provides a very uniform lighting intensity of about 85 lumens per square foot at bench or desk level. The proportions of the inverted semi-elliptic trough reflector are such that none of the tubular light sources are directly visible except from immediately below.

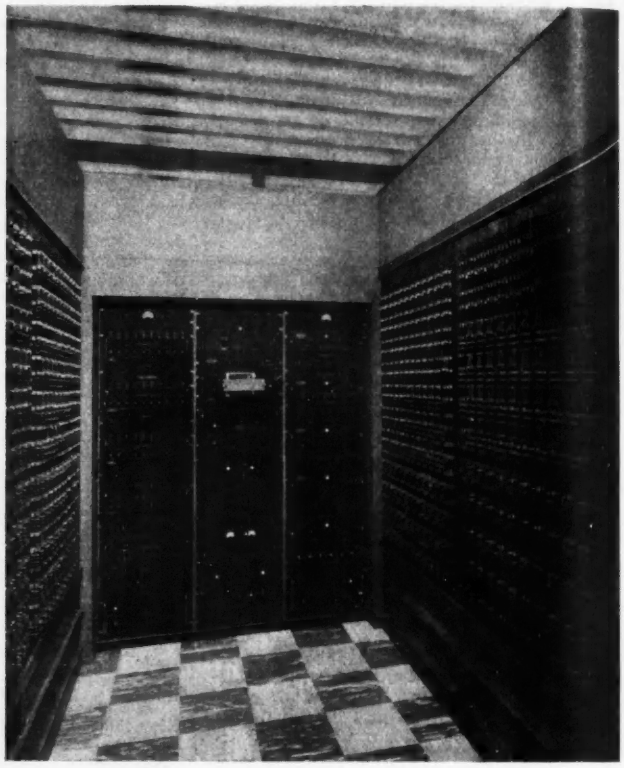
The main control of the lighting is exercised by photoelectric cells mounted in a sheltered position on the north side of the roof. Control is therefore automatic, the lighting panels being switched off in sections according to external daylight conditions. Account is taken of the fact that desks near the windows receive more natural light than those near the centre of the room. Under failing daylight conditions, therefore, a normal sequence of events would be that at a predetermined state the two inner lighting bays of panels would be switched on first and that a further decrease in daylight would then cause the outer lighting bays to be switched on. Alternative control for use during the night or at week-ends is provided by a programme controller. For the use of night patrols pilot lighting is provided throughout the building. It is controlled by a photo-electric cell which operates when the lighting intensity is low.

Heating is by low-pressure hot water circulated from calorifiers and ancillary equipment situated in the plant room in the Depot Road wing basement, the calorifiers being heated by steam supplied by the existing works boiler plant. Main flow and return pipes are run in five vertical brickwork service shafts at various parts of the building to supply the ceiling heating systems.

Throughout the building with the exception of halls, corridors, luncheon rooms, kitchen and lavatories the ceiling heating is associated with the ceiling lighting inverted troughs described above. Continuous fabricated grids of 1in square steel pipes are fixed above ceiling level at each floor and are connected to the flow and return mains in the service shafts, the pipes forming the grid being at 16in centres and running laterally across the building. To the underside of the square pipes are attached, by means of spring clips, continuous rows of the inverted troughing.

Immediately above the heating pipe grid is laid an insulating blanket composed of slag wool in crêpe paper coverings. Besides providing acoustic treatment for the ceilings, this blanket limits loss of heat in the space (which is used as an air extract) between the pipes and the structural floor above. Sufficient leakage of heat upwards is permitted, however, to warm the floor above to such an extent that the maximum variation in temperature from floor to ceiling is only 1 deg. Fah.

A second method of heating is installed in the halls, corridors and luncheon rooms. Here standard perforated flat aluminium sheets, anodised as before and made in 24in squares with all edges lipped are used. They are fixed to the underside of further grids of square piping in much the same way as the main installation and have a similar acoustic blanket above.



Electrical Network Analogue in the Applied Physics Laboratory

The third method adopted is in the kitchens, lavatories and stairways, where a normal embedded panel system is installed, hot water coils being embedded in the ceiling or wall plaster work. Here no acoustic treatment is used and lighting fittings are mounted on the surface of the ceilings. The flat aluminium panels in the halls, &c., and the embedded heating in lavatories are on a separate circuit from those for the heating of the main floors and circulating water temperature is rather lower for this circuit.

Because the Shields Road wing of the building faces north and south and the Depot Road wing faces east and west, greatly different temperatures can be encountered and, for this reason the heating, for control purposes, is separated into four zones, each having independent thermostatic control based on temperatures outside the building. A reduced setting for circuit water flow temperatures is also embodied to meet conditions that exist when the building is not occupied.

The ventilating system provides for a filtered inlet and an extract installation common to all rooms. The inlet equipment supplies a maximum of three air changes per hour and the extract approximately two and a half changes per hour, so that the building is constantly under pressure when the windows are closed. This rate of change can be reduced if required in the cold weather up to 50 per cent by speed variation ; in the summer time the opening hopper windows allow very greatly increased natural ventilation. Additional separate extract systems are also

AN ENGINEERING RESEARCH AND DESIGN BUILDING

The Sir Charles Parsons Memorial Hall

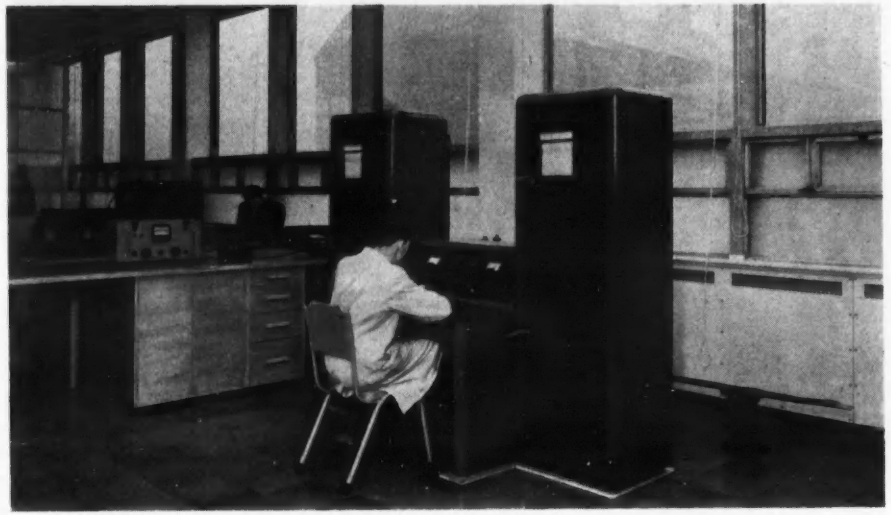
The Mechanical Drawing Office

The Depot Road Wing Containing Research Laboratories and Technical Offices

Part of the Mechanical Creep Testing Laboratory

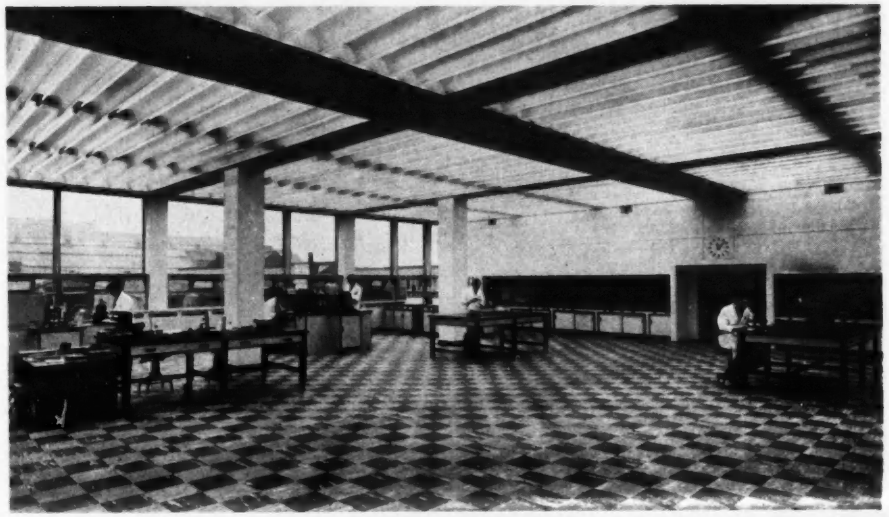
LABORATORIES IN AN ENGINEERING RESEARCH AND DESIGN BUILDING

Part of the Electrical Laboratory



An Alternating Current Bridge in the Electrical Laboratory

Apparatus for Heat Transfer Measurements in the Applied Physics Laboratory



Part of the Chemical Laboratory

provided for all lavatories, kitchen and laboratories.

The inlet fans and air filtering equipment are situated in a chamber on the south-west corner of the roof, one wall of which is entirely constructed of plate glass louvres in anodised aluminium frames. Air filtration is by means of high-voltage electrostatic filters and between this equipment and the inlet fans are incorporated steam heater batteries which maintain the air at a given temperature at the room inlets throughout the system.

Two 72in diameter fans supply the incoming air to the whole building, the first dealing with 75 per cent of each floor in the Depot Road wing and the second with the remaining 25 per cent and the whole of the Shields Road wing. Damper controlled by-pass arrangements are provided to allow a reduced quantity of air to be passed to each wing should either fan be closed down. Distribution is by galvanised sheet steel trunking through the vertical service ducts, with branch trunks run at all floors in the space between the thermal blanket which covers the lighting and heating panel ceiling and the structural floor above. Ceiling anemostats are connected to these branch trunks forming a regular pattern in the flat areas of the ceiling and discharging air to the rooms.

Different methods are used for air extraction in each wing. In the Shields Road wing, the corridor ceilings have been constructed at a lower level than the room ceilings, and the space above the ceilings is used as a main extract duct for each floor, grills being fixed at high level in the partition walls of the rooms. The ceiling ducts thus formed above the corridors in turn discharge through a damper-controlled opening into one of the vertical brickwork service shafts which, in itself, is the main extract trunk for the Shields Road wing, and the outlet from this shaft is extracted by a fan in the plant room on the roof.

On all floors in the Depot Road wing extract grills are fitted in continuous lines in false wall panelling below the window sill level. The space behind this wall panelling forms a sealed extract duct on both sides of the rooms. A series of holes left in the floors behind this panelling allows the extract air to be drawn into the ceiling space of the room below, in which there are also the galvanised air inlet trunks, lighting transformers and other equipment. The whole of the space above the ceiling is thus one complete extraction duct and the air is drawn from it at each floor by damper controlled openings which again connect with the remaining four vertical brick service shafts that are situated at the corners of this wing. These, in turn, form main extract shafts and again air is discharged by batteries of fans placed in the roof plant rooms.

The separate extracts from the lavatories, kitchen and laboratories are run in galvanised or asbestos cement trunking within these brickwork service shafts and extracted at roof level by separate fan equipment. All controls for the ventilating equipment are grouped together with controls for the heating in the calorifier room in the basement.

The Research Block

In the foregoing description enough has been said to show how the broad concept and the detailed planning of the new building have been directed towards the ideal of providing first-class working conditions that will encourage research and design shafts to give of their best. It only remains to give some indication, based on impressions gained from a recent visit to Heaton works, of the activities that animate the new research wing.

The main concern of the company is the development and manufacture of plant for electrical power generation and transformation. Its products include steam and gas turbines, electrical generators, compressors, and transformers, and it is the function of the research organisation to provide the means of improving the design and application of these products. Much of the research and development work is therefore directed toward the solution of specific problems. But because neither the worker nor the firm would benefit in the long run by an exclusive interest in *ad hoc* research a healthy leaven of more fundamental work is introduced.

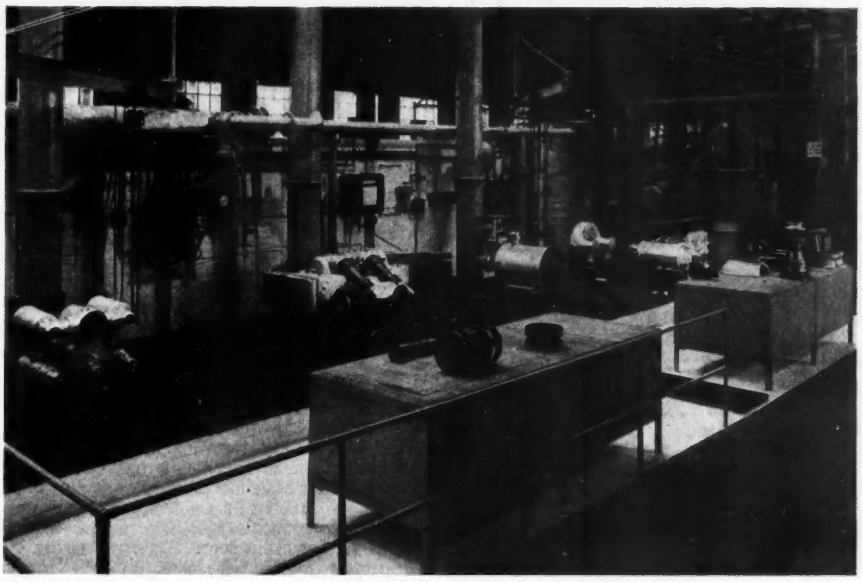
In general, research work involving lighter apparatus is concentrated in the new research wing, while the heavier and more noisy equipment is accommodated in adjoining buildings. For example, the original building which housed the old electrical laboratories in the angle of the "L" formed by the new building is being converted into a laboratory which will be devoted solely to high-voltage work. The new electrical laboratory (Plate 4), which occupies about half of the ground floor in the Depot Road wing, is equipped for electronic, insulation and low- and medium-voltage investigations, as well as for instrument development and standardisation and fundamental vibration studies. A typical example of the work of this department is illustrated in one of the photographs reproduced on Plate 4, showing an a.c. bridge which was designed and built by the company for making dielectric loss measurements on alternator stator coils. During our visit to the laboratories we also saw under development a method of obtaining an accurate measurement of the speed of a rotating shaft. In this method a beam of light is reflected from the shaft on to a photo-cell. Part of the shaft is painted black so that the beam of light and, therefore, the output of the photo-cell is interrupted, say, once per revolution. By connecting the output of the photo-cell to an amplifier and thence to a counting circuit embodying a series of "Dekatron" tubes, a count can be made of the number of revolutions made by the shaft.

The services in the electrical laboratory, including a.c. and d.c. supplies, are laid in readily accessible floor ducts and are brought up to connection pillars which are sited in convenient positions for coupling to instrument and work benches. Multi-core interconnection cables allow quick connection to be made from the source of one experiment to another and to other laboratories. Common service equipment such as cathode-ray oscillograph instruments is arranged on specially designed trolleys for easy transference to any part of the laboratory. Glass partitioned study and report rooms, with the necessary drawing-office facilities, are provided at one end of the laboratory.

In accordance with the policy of excluding from the new building all noisy experimental work, aerodynamic and combustion research will continue to be done in existing laboratories. These buildings, together with the high-voltage laboratory referred to above are, by design, so situated in relation to the new block that the whole forms, in effect, a "Research Square." Provision is, however, made for mechanical research facilities in the new block, particularly those relating to fluid flow investigations.

Up-to-date chemical and metallurgical laboratories (Plate 4) and an applied physics laboratory complete the research facilities in the new block. In the creep laboratory of the metallurgical division six standard Dennison creep machines and a twelve-specimen machine are installed (Plate 3). They facilitate investigations which are of particular interest to the company and which are not normally catered for in the very extensive creep laboratories in steel works and in such institutions as the N.P.L., Admiralty and Mechanical Engineering Research Board. Tests now in progress are designed to show the behaviour of welded components and cast steels when subjected to creep conditions and long-term tests are in hand of heat-resisting steels in current use on actual machines. By this means their properties are checked during the operating life of the machine.

The increasing use of higher temperatures in gas and steam turbines gives new emphasis to problems associated with thermal stress, which is one of the reasons why the applied physics laboratory has been specially equipped to deal with heat transfer investigations. Specially constructed "heat cells" (one of which can be seen in Plate 4) allow of accurate measurement of the transfer of heat a wide variety of conditions. One of the results of this basic information has been the development of regenerative heat exchangers specially suited for gas turbine operation. The photograph reproduced above illustrates the test bed in another part of the works, where a number of such heat exchangers are now undergoing development.



Test Bed for Heat Exchangers Under Development

Included in the equipment of the applied physics laboratory is an analogous electrical network (illustrated on page 398), which enables estimates to be made of the static and transient temperature distribution and thence the thermal stress in such components as turbine discs and rotors. The analogy is based on the correspondence between voltage and temperature, current and heat flow, electrical resistance and thermal resistance, electrical capacitance and thermal capacity. Thus, to correspond with a given shape of rotor, an electrical network may be set up and voltages proportional to the gas temperatures applied to it. The voltage/time relationship at every point in the network is recorded on film and the traces, to scale, give the temperature/time variations at the corresponding points in the rotor. The applied physics laboratory also undertakes complicated stress analysis for both stationary and rotating components and, where necessary, to this end collaborates with the electrical research division in the use of strain gauge apparatus with which the department is well equipped.

One's final impression from a visit to the Heaton works is that the new research and

Part of the Chemical Laboratory

Apparatus for Heat Transfer Measurements in the Applied Physics Laboratory

design building forms a worthy tribute to Sir Charles Parsons, who founded the company. On leaving the building, as on entering it, one is drawn towards an annexe opening from the main hall, dedicated as the Sir Charles Parsons Memorial Hall, a portion of which can be seen in one of the photographs reproduced on Plate 3. In this Memorial Hall the visitor may see a number of showcases containing interesting specimens and models of Sir Charles's original work. The west wall is adorned with a sculptured plaque of Sir Charles executed in Carrara marble by Sir William Reid Dick, R.A., and on the north wall there is a portrait from a painting by Sir William Orpen, R.A.

Effective Utilisation of Material

By FRANK NIXON*

No. I

In this paper, which was read by Mr. Frank Nixon before the Institution of Production Engineers, Derby Branch, December 14th, and abstracted herewith, the author discusses the ways in which design, development, research, scale of production, and the forming methods adopted can dictate the effectiveness of material utilisation in prime movers.

BEFORE going on to consider the more fundamental issues, it will be interesting to obtain a rough idea of some typical figures of material utilisation which are being achieved.

After physical properties and general suitability for the purpose, availability and market price of materials are the measures applied by the designer and the production engineer in making their choice. Fig. 1 shows diagrammatically the relative costs of the metals used in engineering, in the forms usually employed. These costs can only be approximate, since they vary according to quantity and quality. Leaving aside titanium, it will be seen that the most expensive metals are about sixty times as costly as the cheapest. These costs indicate the overall difficulty of obtaining the ores, of converting them, and manipulating the crude metal into its usable form.

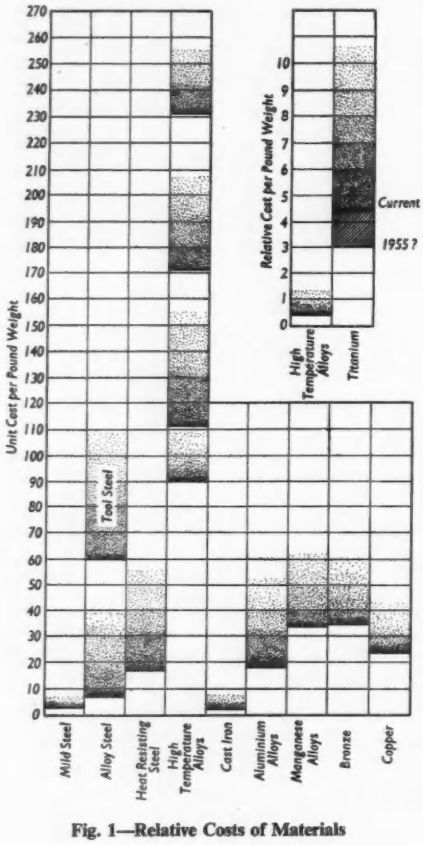


Fig. 1—Relative Costs of Materials

* Assistant General Manager, responsible for new manufacturing processes, Rolls-Royce Ltd.

It is not generally appreciated how great are the quantities involved in the production of metals. A blast-furnace producing 1000 tons of pig iron per day, for example, requires at least 2000 tons of ore, 800 tons of coke, 500 tons of limestone, and 4000 tons of air. In earlier days the blast-furnace was sited close to the source of supply, but nowadays the iron ore may have come from Spain or Australia. Similarly with aluminium, the bauxite will probably have been mined in British Guiana and converted in Canada. Eight pounds of bauxite are required to produce 1 lb of bar and, in addition to the thousands of miles of transportation, about eight units of electricity will have been consumed.

The conversion of ingot into usable forms such as bar or sheet involves a mill loss of 40 to 50 per cent. With static castings the yield from the metal melted may vary between 45 and 65 per cent. In drawing bar into wire rod there will have been a loss of about 5 per cent, and a further loss of 5 per cent in drawing the rod down to wire. Although the material cropped from the ingot and machined from the billet, and the runners and risers from castings, will go back into the furnace, this recovery may require more or less refining, depending upon the alloys in question.

Unfortunately, the higher the alloy the more difficult usually is the recovery, and in the case of titanium it is not at the moment possible to reconvert the waste back into the original alloy.

To complete the material picture, Fig. 2 gives an indication of the effect of form on cost. The magnitude of the variation depends largely, of course, upon the alloy and on the quality specified, and it is interesting to note in passing that those forms from which the highest material utilisation figures are obtained, i.e. wire, sheet and strip, are the more expensive ones.

Utilisation of the material used in the manufacture of products varies enormously. At the one extreme we have the wire cable and the impact extruded tooth-paste tube, with figures of 97 per cent and higher. At the other extreme the figure may be as low as 10 per cent where much machining has had to be carried out. Machinery, which usually comprises an assembly of a greater or lesser number of detail components, will usually have overall values varying from something approaching 40 per cent for the aircraft engine to 60 per cent or more for mass-produced domestic equipment. It is important to realise that a high figure does not necessarily signify an efficient product. In the case of prime movers, for example, it is probable that the highest figures for all time were those of Thomas Newcomen's atmospheric engines.

We have all seen textbook examples of the great savings achieved by changing from a casting to a weldment, from a weldment to a pressing, from a pressing to a forging, from a forging to a casting.

While these figures are undoubtedly true for the examples quoted, they often fail to pay any regard to more than the simple facts of cost of material consumed and labour required, and assume that both alternatives are equally suitable for their purpose, and that production equipment, knowledge, skill and technique already exist and are available. The costs incurred in achieving a saving in material need to take account of these factors, and it will not infrequently be found that a reduction in material utilisation may result in a more successful product, i.e. in better effective utilisation of material.

FACTORS AFFECTING THE EFFECTIVE UTILISATION OF MATERIAL

Fundamental Design.—Many of us will remember the large turnip pocket watches of our grandfathers, and the modern wristwatch is not only a good example of overall material economy, but of greatly increased convenience to the user. So, too, is the miniature camera. In our houses large reductions have been made in the material content of locks (and keys), bolts and bars, which are at least as effective, and far more æsthetically pleasing, than those still seen in old houses, and which, incidentally, have hardly changed since the days of the Romans.

Then, too, we have from long usage become accustomed to seeing large relatively slow-moving steam engines and diesel engines applied to stationary and marine work, and only in the air and on the roads have we seen anything approaching an effort to put the material of prime movers to really effective use. And now in these fields the gas turbine is providing a striking example of the influence of fundamental design. Whether it is applied to air, marine, or stationary duties, this type of engine produces power for from one-third to one-seventh the weight of the lightest equivalent power unit.

Thus in the stationary field the Ruston and Hornsby Mark T.A. gas turbine engine has a continuous rating of 1200 b.h.p. for a basic weight of 12,300 lb, which is stated to be one-third the weight of the best equivalent engine. In addition, there are other great savings in the installation, since no heavy foundation is required, and no cooling system, no water softeners, no coal bunkers, and no ash disposal plant.

In the marine field the Rolls-Royce marine gas turbine "RM.60" produces 5400 b.h.p. for 29,000 lb weight. As installed in the "Grey Goose," two of these engines displaced two 4000 b.h.p. steam turbines which were the lightest steam power units of their kind ever produced, but which weighed twice as much. In addition, the "RM.60" engines require 25 per cent less space and give 30 per cent lower specific fuel consumption.

The "Avon" Mark I engine has a static sea level thrust rating of 6500 lb to 7500 lb, depending upon the model. It weighs, complete with its jet pipe, 2710 lb, and it is used to power the "Comet II" aircraft. To propel this aircraft through the air at its continuous cruising speed of 500 m.p.h. at 40,000ft requires about 10,000 h.p., or 2500 h.p. from each engine. The highly supercharged "Merlin 724" piston engine weighs dry 2400 lb, but with radiator and coolant, oil cooler, propeller and exhaust system, &c., i.e., as a "going engine," about 3600 lb. At 40,000ft it could deliver 450 h.p., or effectively, assuming 80 per cent propeller efficiency, 360 h.p. Admittedly the engine was not designed to operate at this altitude, but it is obvious that the "Avon" engine is making far better use of its material. And if we try to visualise what the "Comet II" would look like if in some nightmare its designer tried to power it with "Merlins,"

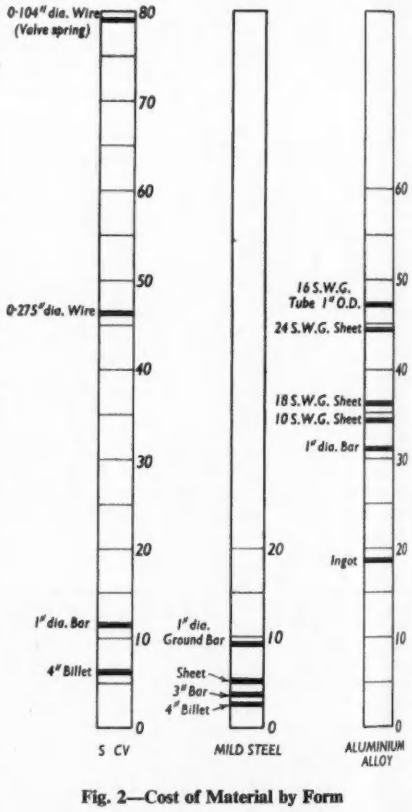


Fig. 2—Cost of Material by Form

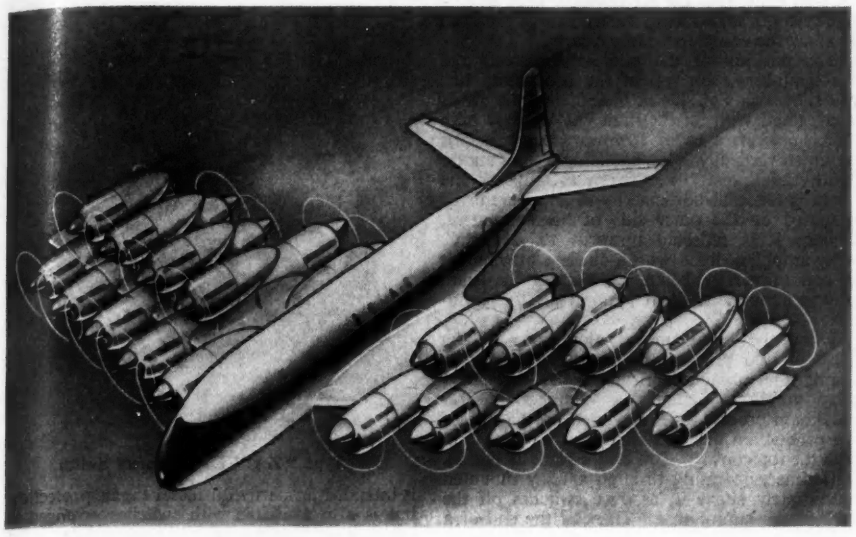


Fig. 3—A Hypothetical "Comet II" if Fitted with "Merlin" Piston Engines

we would get something like the apparition shown in Fig. 3.

At the other end of the horsepower scale we have the small French gas turbine, the Blackburn "Turbomeca Artouste I" and "II," giving continuous powers of 226 b.h.p. and 325 b.h.p. for 183 lb and 200 lb weight respectively.

While in these examples there are great savings as compared with the equivalent power units, there exist also between themselves wide differences of material utilisation, as shown by the weight per horsepower figures. We may turn for a moment to the reciprocating oil engine and see what might be achieved here by a different basic conception.

If the normally accepted solutions are examined critically, it is difficult to see why the typical stationary and marine diesel engines are such huge heavy monsters. The reason is most probably that given by Sir Harry Ricardo: "One cannot escape the suspicion that the use of very large diesel engines at sea is due, as Sir Alfred Ewing suggested recently, 'rather to the taste and fancy of some dominating personality than to a careful weighing of arguments such as appeal to engineers.'"

In 1931 and again in 1933 Sir Harry strongly pressed the advantages of using a multiplicity of small high-speed diesel engines instead of the large ones which were, and are still, the prevailing fashion. He showed that the weight per horsepower fell appreciably as engine speed rose and engine size was reduced, and though the cost per ton of the high-speed engine might be treble that of the slower engine, the resulting cost per horsepower of the high-speed engine was only about one-quarter that of the slow one.

Further interesting examples have been given recently of the reductions in weight and real cost of typical motor-cars, amounting to 25 per cent in twenty years. In addition, by the adoption of a V arrangement of cylinders for the engine a 20 per cent saving in weight of power plant is possible.

Detail Design.—Within the bounds laid down by the basic design the designer is able to exert a considerable influence upon the product. He will give due weight to a number of considerations having an important bearing upon the way in which the material is used. These include some or all of the following, depending upon the type of thing under consideration:—

(*a*) Purpose and function of product.
(*b*) Performance.
(*c*) Cost.
(*d*) Weight.
(*e*) Appearance.
(*f*) Ultimate life.
(*g*) Running cost.
(*h*) Overhaul cost.
(*i*) Scale of production.
(*j*) Availability of desirable materials.
(*k*) Manufacturing facilities available.

The relative importance of these factors will vary enormously with the type of product and with the rate and scale of production anticipated for it. For example, a casting left rough will give a higher material utilisation figure than a machined-all-over part, but if it entails lower safe working stresses and increased weight the net result might well be worse. It is only by analysing all the factors that the best result can be obtained, and here a certain amount of give and take by both designer and production engineer is essential for success. This interplay of influences is only effective, however, if the two parties are properly matched. Much has been heard of the American way, where the production engineer has too often overwhelmed the designer, with the result that while there might be overall cheapness and high rate of output, there is inflexibility and a tardiness to take advantage of developments in design thinking. In this country excellent results have been obtained by designers forcing the pace, but this succeeds only when they are matched by production engineers of comparable ability and of sufficient strength to apply the curb when it becomes absolutely necessary.

Mention has already been made of the advantages of small light oil engines. The aircraft engine provides an even more striking example. In order to obtain the highest performance with minimum weight the aircraft engine designer works his engine at the highest temperatures feasible with available materials and he works those materials at the highest possible stresses. This means that expensive special alloys are specified where necessary, and there is no hesitation in calling for what in other fields might seem to be an excessive amount of machining. Yet the net result is that the prime cost per brake horsepower at continuous rating is appreciably lower for the aircraft engine of the type under review than for any other type of engine in its power class. This is due partly to the quantities produced, but largely to the fact that the increased cost of material and of the greater amount of machining are more than compensated by the increased amount of work done by the material.

Interesting light is thrown on this by a comparison of the "Merlin 724" and the "Avon" Mark I engines. In the bare engines the overall material utilisation figures are about the same, but the average cost per pound of the raw material used for the "Avon" is roughly double that of the "Merlin." The manufacturing man-hours per pound are much higher in the case of the "Avon," due to the difficult shapes and still more to the difficult materials employed. Yet the cost per continuous horsepower of the "Avon" Mark I, even at its present early stage of development, is roughly half that of the "Merlin" under equivalent conditions, and this ignores the additional cost of the airscrew, radiators, cowling, &c.

With all this the aircraft engine designer has to keep a careful eye upon the strategic content of his alloys, which may contain high percentages of nickel, chromium, molybdenum, cobalt, &c. It is interesting to note here that in addition to their being technically well ahead, British aircraft gas turbines employ far less of the strategic alloys than do the American engines, and this is another example of effective utilisation of material.

An example of this is seen in the case of the "Nene" turbine disc (Fig. 4). This was made originally from a forging weighing 148 lb, in a strategic alloy. By applying air cooling to the

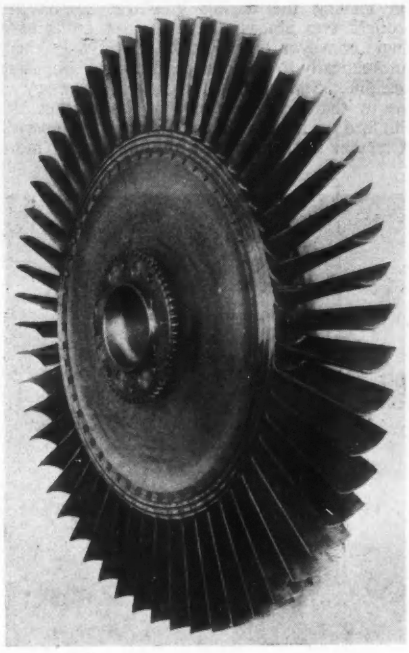


Fig. 4—"Nene" Turbine Disc

disc it was possible to use instead a much lower alloy, and at the same time to reduce the weight of the finished disc by 24 lb. The net saving in cost of the forging was £89. Incidentally, this disc transmits 10,000 h.p.

Where the overriding considerations of performance and reliability permit, the designer can help greatly by making provision for easy replacement of vulnerable parts. By keeping the number of different parts to a minimum there are savings at every stage, but in addition there can be, too, an appreciable saving in material, through reduced discards as well as reduced holdings of raw material and spares stocks.

Whatever the product, the designer can play a great part by refraining from calling unnecessarily for materials which are difficult to obtain, for tolerances requiring new machines or inspection equipment or leading to a higher rejection rate, for modifications involving wastage of material and jigs and fixtures and tools.

(*To be continued*)

Bridge Over the River Meuse

A NEW bridge over the River Meuse connecting Belgium and the Netherlands was recently erected at Maaseik.

The bridge is a steel plate girder structure with a total length of nearly 500ft in three spans, of 158ft, 184ft and 158ft. The main girders are spaced 5·8ft apart and are braced by stiffening girders and the total weight of steelwork in the bridge is 693 tons. The decking carries a reinforced concrete slab, accommodating a 23ft wide roadway and two cantilevered footpaths, each 6½ft wide. The new bridge is a rather slender structure of pleasant appearance. It was designed by the Belgian Ministry of Public Works; Ateliers Baume and Marpent were contractors for the steel superstructure, and Etude and Ouvraison Cie was responsible for the construction of piers and abutments.

Photo-Electric Control Equipment for Plasterboard Production Lines

PHOTO-ELECTRIC control equipment has been installed by The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, to facilitate uniform production flow of plasterboard sheets at the Rochester factory of Gyproc Products, Ltd.

In the manufacture of Gyproc plasterboard the sheets, which may vary in length from 6ft to 12ft, are passed through a long drying kiln by six conveyors mounted one above the other. On leaving the drying kiln the boards are brought two abreast, from the six decks to a single conveyor line (Fig. 2) which takes them automatically to an edge grinding and bundling machine. Some form of control is necessary to ensure that the six conveyor lines from the kiln feed the boards on to the single line conveyor at regular intervals and to prevent two or more

Fig. 1—Lamphouse (Left) and Photocell (Right) Mounted above Rollers

conveyor lines from feeding the boards on to the single board conveyor at the same time. Each of the six conveyor lines leaving the drying kiln leads to its own motor-driven speed-up conveyor section which, when switched on, shoots the board on to the single line conveyor. The photo-electric control equipment ensures that none of these conveyor lines can feed on to the single line conveyor until the previous deck has been cleared; process timing equipment allows the operator to pre-set the interval between each deck, to suit the particular length of board which is in production at any one time.

In Fig. 3 we show the beginning of the roller take-off system for the six conveyor lines leaving the drying kiln, with the safety guards removed to show the equipment more clearly.

The position of the photo-electric cell and the lamp-house on top of the production line are shown in Fig. 1. A G.E.C. lamp-house is used, fitted with an "Osram" 24W, 12A bulb which projects a beam downwards on a mirror mounted vertically below the lamp-house, underneath the lowest belt. From this mirror the beam is reflected horizontally to another mirror mounted on the other side of the equipment, whence it is reflected upwards to a G.E.C. relay amplifier, fitted with a 4in lens attachment to concentrate the beam. Altogether the beam travels about 20ft from lamp-house to photocell.

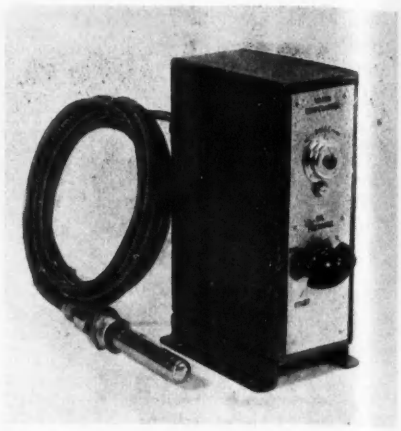
When the board moves along one of the decks of the production line it interrupts the beam; the photocell, through the associated relay amplifier, actuates a Chamberlain and Hookham process timer mounted on the side of the production line (the timer can be seen level with the top conveyor belt on the right of Fig. 3). This timer, operating through a relay mounted immediately above it, at once switches off the bulb in the lamp-house. Then, at the end of a timed interval which can be anything from 0 to 100 seconds, the process timer operates a Witton-Kramer solenoid to switch on the electric motor rotating the rollers for the next conveyor line take-off, and, at the same time, to switch off the motor driving the previous line. Simultaneously the process timer, through its associated relay, switches on the bulb in the lamp-house again, so that the equipment is ready for the next set of Gyproc boards passing through.

By adjusting the setting of the process timer it is possible to allow for differences in speed through the kiln (due to different thicknesses of Gyproc board requiring different drying times); similarly, the intervals between successive boards on the final single belt can be smoothly controlled. Since the light beam from the lamp-house is passed through both sides of the production line, the photo-electric control equipment will still operate even when a single board occupying only one side of the conveyor belt, passes through.

Three Engine Safety Components

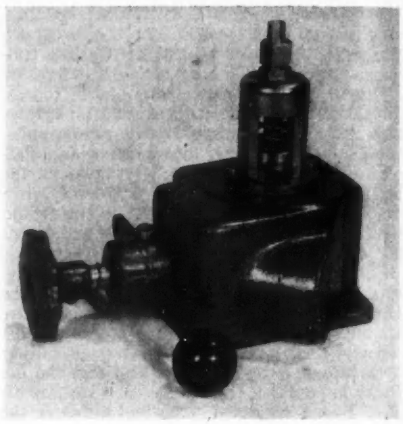
THREE new components have been designed and manufactured recently by Teddington Industrial Equipment, Ltd., Sunbury-on-Thames, Middlesex. They are "Teddington" type "ZV" engine safety switch; "Teddington" type "YA" oil pressure failure device, and "Teddington" type "ZW" protection unit for diesel-powered air compressors.

The safety switch, as illustrated, is a dual-purpose unit for operating either a visual or audible alarm or any of the standard "Teddington" solenoid-operated shut-down devices. It



Type "Z V" Engine Safety Switch

is intended primarily for diesel engine protection, but is also available with switches arranged to earth the magneto of a petrol engine. The standard instrument is sensitive to lubricating oil pressure and to coolant temperature, while other models have two elements responsive to



Type "YA" Oil Pressure Failure Device

coolant and oil temperatures or have three elements responsive to oil pressure and coolant and oil temperatures. A simple knob is incorporated which puts the oil pressure switch out of action while the engine is being started, and when the engine reaches normal speed the control is switched to "auto" protected position.

The oil pressure failure device, shown above,

Fig. 2—Six Conveyor Lines Feeding Plasterboard on to a Single Line Conveyor

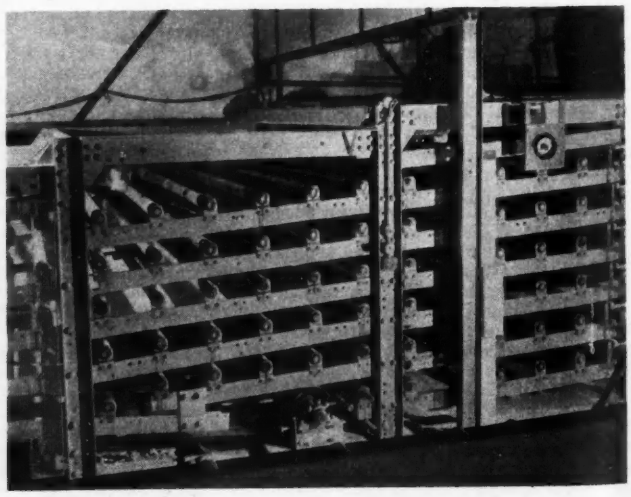
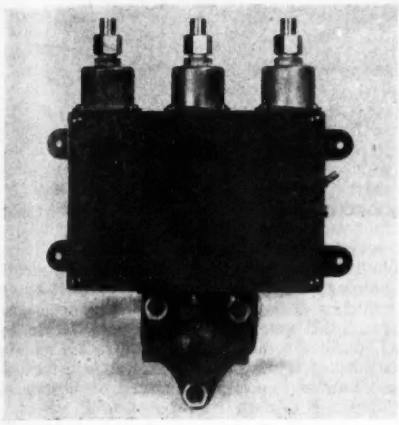


Fig. 3—Plasterboard Take-off System from Drying Kiln. The Light Projector for the Photocell is above the Top Row of Rollers (Left) and the Process Timer is on the Right

is designed to protect one operational function only, namely, failure of lubricating oil pressure, but it can be supplied to protect the engine from excessive coolant temperature. A bellows unit, sensitive to oil pressure, forms the operating element and it can be adjusted over the normal range of lubricating oil pressures. It is designed for mounting near the engine throttle and is fitted with a spring-loaded operating lever which is connected to the throttle and normally returns to the "throttle closed" position when free to move. A spring-loaded latch holds the lever, when in use, in the "throttle open" position. Should the lubricating oil pressure fall to a preset value, the operating element releases the latch to allow the lever to move back to the "throttle closed" position.

The protection unit, illustrated here, has



Protective Device for Diesel-Powered Air Compressors

been developed to meet the requirements of diesel-driven air compressors where no electric supply is available, and to provide automatic protection against failure of diesel engine and compressor lubricating oil pressure and excessive intercooler pressure. In the event of the lubricating oil pressures falling below a predetermined value, the control operates a small integral air valve to allow the application of the air pressure from the compressor receiver to the pneumatic piston attached to the diesel fuel pump. An increase in intercooler pressure above a preset level also operates the valve. All three elements, which are externally mounted, are independently adjustable and there is a manual reset lever which must be held in the operating position until normal operating pressures are established.

Narrow-Gauge Diesel Locomotives

Two new diesel locomotives, one fitted with a 20 b.h.p. and the other with a 30 b.h.p. engine, for use on narrow-gauge tracks from 1ft 6in to 3ft 6in, are now being made by Ruston and Hornsby, Ltd., of Lincoln. These locomotives are each made in two types, one for service on the surface and the other for underground haulage in naked flame mines. Each type is available in six models with working weights ranging from 3½ to 4½ tons, and fitted with two or three-speed gearboxes. All models of the locomotive have an overall length of 7ft 6in and a 2ft 7½in wheel base.

Two or three-speed constant-mesh gearboxes fitted to the locomotives are operated by low-pressure hydraulic fluid and a separate cone clutch is engaged for each speed. The drive is transmitted directly to the clutch shaft by a flexible coupling, and this shaft carries the housings, clutch facings and spinners. These clutch spinners are moved axially by the oil pressure to engage on the clutch faces, and the spinners are connected by dogs to their respective gears, which are mounted on roller bearings. Pressure fluid for operating the gearbox is provided by a pump driven from the primary shaft, and a relief valve maintains a steady oil pressure.

When a gear is selected pressure fluid is fed

Diesel Mine Locomotive

from a control unit through internal piping and passages in the clutch shaft to engage the appropriate clutch. The selected clutch transmits the drive to the final driving shaft through gears on the lay, intermediate and final bevel pinion shafts. For reversing, a dog clutch between the bevel wheels on the final drive shaft is engaged, and the control system interlock ensures that the direction change lever cannot be operated whilst the speed control lever is in the driving position.

The drive from the gearbox is taken equally to the two axles by roller chains. The plain bronze bearing axleboxes are each carried on a single coil spring, and by pivoting these axleboxes a degree of radial movement is given on the spring action to maintain the chain centres. Lever-operated brakes act on all four wheels and sanding gear is provided at each end of the locomotive. A water-wash exhaust scrubber is fitted on the mines locomotives to remove the irritant constituents of the exhaust.

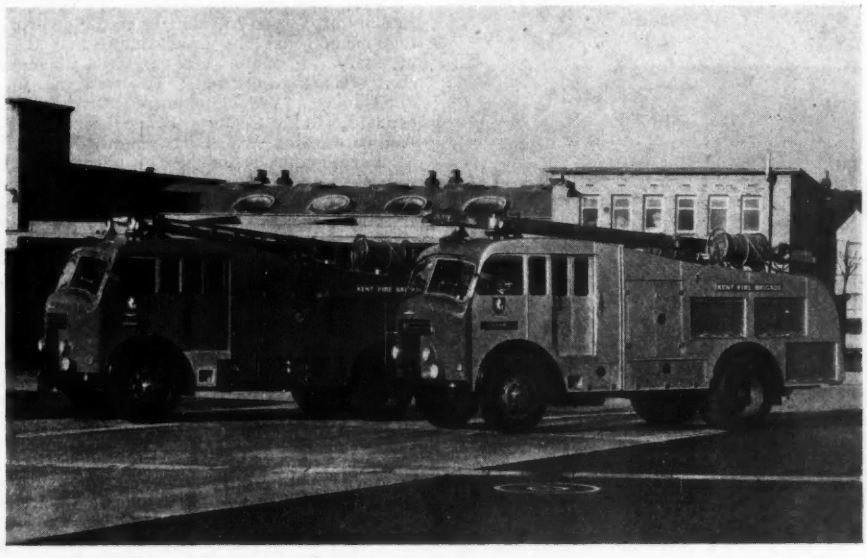
One of the mines locomotives can be seen in operation in the photograph above. The surface locomotives are similar in all respects except that they can be fitted with driver's cab or canopy.

Fire Fighting Vehicles' Surface Finish

THE traditional colour associated with fire fighting appliances is red, but the need to use this colour as a distinguishing mark is no longer necessary and, indeed, of little value since so many other vehicles are also coloured red. A high gloss finish is easily damaged and not essential when the operational use of the vehicle is considered, and the Kent Fire Brigade has given some thought to the advantages of a more utilitarian or functional finish in the interests of economy. Plastics and aluminium were considered and aluminium was adopted finally as the new finish.

On Wednesday of last week we were able to visit a display of vehicles of the Kent Fire Brigade, held at Rootes Showrooms, Maidstone, and see some vehicles having the new finish. The appliances shown all consisted of a body built by Hampshire Car Bodies, Ltd., mounted on a Commer chassis and included one painted in the traditional colour, another with unpainted sides panelled in aluminium sheet having a matt finish, and a third having side panels of embossed aluminium. Our photograph shows two "B" type water tenders, one painted and the other having an embossed finish. Each vehicle is built on a 5-ton Commer chassis, driven by six-cylinder, 109 b.h.p. under the floor engine, and carries an extension ladder and a detachable light pump in addition to a built-in 500-gallons per minute Dennis fire pump driven from a split transmission pattern power take-off. Four hundred gallons of water are carried and about 3000ft of hose and also two reels, each having 180ft of tubing. The aluminium used in the construction of the vehicle having the new finish was introduced last year by the British Aluminium Company, Ltd., and this new industrial finish—embossed aluminium—is produced in two grades known as "light and heavy stucco." The appliance on view is panelled in 18 S.W.G. sheet of 99 per cent purity aluminium in the half-hard condition and having a "heavy stucco" finish. The other vehicle on view was a ladder pump appliance, built on a 5-ton Commer chassis and carrying 100 gallons of water. This vehicle is panelled in 18 S.W.G., half-hard, 99 per cent commercial purity aluminium sheet, which has been given a matt surface by rubbing over with wire wool. Both vehicles incorporate chequer plate of 20 S.W.G., 99 per cent commercial purity aluminium for tread and kick plates, all supplied by the British Aluminium Company, Ltd.

This adoption of a utility finish does mean a



Two Fire Engines. On the Left is the Conventional Red Paint Finish. On the Right is the Embossed Aluminium Finish

saving in both initial cost and maintenance charges, since the aluminium surface is not painted and does not need expensive polish to obtain a high gloss finish. The material is cleaned easily and inexpensively, whereas the painted surface requires constant retouching and a repaint at intervals during the useful life of the vehicle. It is estimated that the new surface will effect a saving amounting to as much as £1800 on the appliances to be added to the Brigade fleet in the next few years, and that a further substantial amount will be saved on repainting.

In contrast with the modern appliances, and associated with the display, were a number of museum pieces of fire fighting equipment, including an eight-man manual engine, dated 1773, which was used at Sandwich and could be hired for two guineas with an additional charge of one guinea for the horse. The men were paid 6d. per hour with an allowance of 9d. for refreshment. There was also a seventeenth century four-man manual pump, used at Lullingstone Castle, and a wooden hose cart, used for the transport of heavy leather hose across the roof walks of Canterbury Cathedral. A more modern example was a steam fire engine, built by Shand, Mason and Co. in 1905 for the Hythe Fire Brigade, which saw service in the second world war as a base pump for the emergency water system.

Slideway Grinding Head

PARTICULARS have been received from J. Brockhouse and Co., Ltd., Penn Road, Wolverhampton, of a grinding head which has been developed for attachment to surface grinding

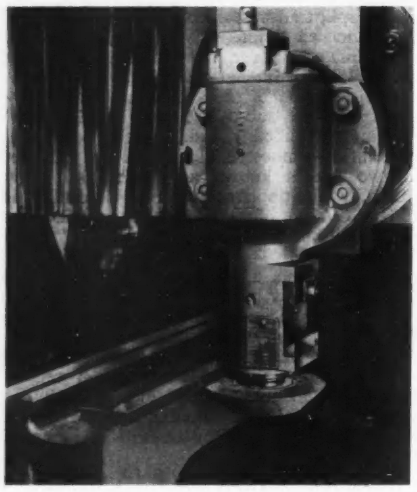


Fig. 1—Vertical Grinding Head fitted on a Planing Machine

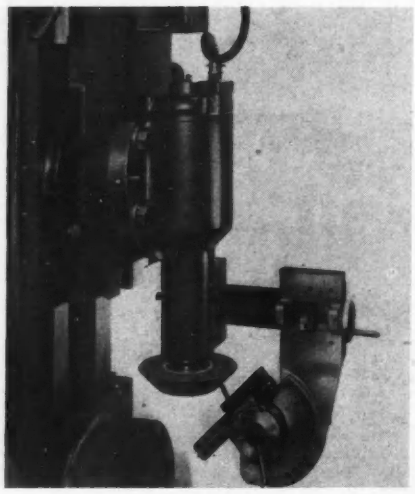


Fig. 2—Vertical Grinding Head and Wheel Truing Device

planing and other machine tools, and used for grinding all the faces on a variety of machine slideways at a single setting. In Fig. 1 on this page, a vertical grinding head can be seen mounted on the tool slide of a planing machine and grinding the slideways on a machine bed. The vertical grinding head has a 2in diameter spindle carried on precision bearings and driven at 3000 r.p.m. by a 2 h.p. motor. It is suitable for grinding wheels from 2in to 7in diameter and when used with cup or saucer wheels this head meets the requirements of a wide range of machine tool slideway designs. The head is dowelled in a vertical position, but if required it can be rotated 90 deg. each side of the vertical.

The special truing device shown in Fig. 2 is mounted in ways at the side of the head. As can be seen, the diamond holder is carried on a graduated swivel head, and by means of the small lever on the side the diamond is reciprocated over the grinding wheel through a rack and pinion. The truing head can be adjusted up to 80 deg. each side of the centre line, and positioned by locating bushes at 5 deg. intervals. With this truing device, and by using cup wheels for both edge grinding and peripheral grinding in a very large number of cases, all the grinding operations on a slideway can be carried out at a single setting.

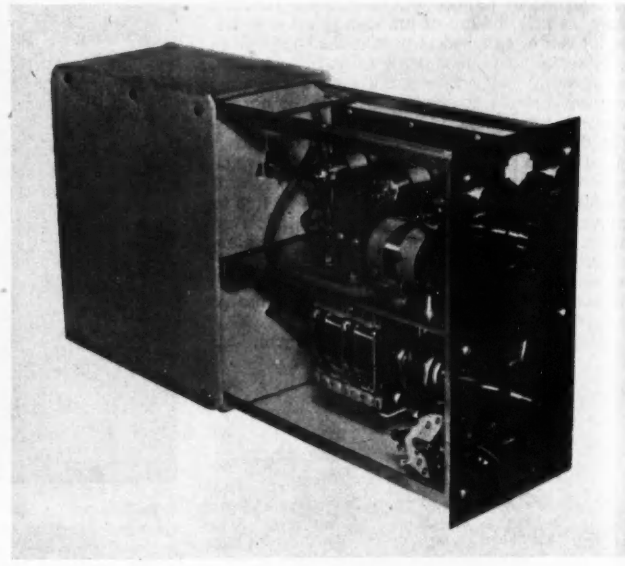
The firm also makes a horizontal grinding head for slideways. This head is driven by a 5 h.p., 3000 r.p.m. motor and takes wheels up to 14in diameter and 2in wide. It is fitted with a diamond wheel truing attachment mounted on a swivel head and having an angular adjustment up to 80 deg. each side of the centre line.

Stable Variable-Frequency Oscillator for Centralised Transmitter Drive Units

THE frequency of medium and high-power radio transmitters in the band 4 to 30 Mc/s must (under International Telecommunications Union Regulations) be kept within 0·003 per cent of its nominal value at all times. To achieve the necessary degree of frequency stability, it is usual to resort to crystal control; this method has the disadvantage that it is necessary to obtain new crystals whenever channels are reallocated. To overcome this disadvantage, the Equipment Division of Mullard, Ltd., Century House, Shaftesbury Avenue, London, W.C.2, has recently developed a variable-frequency oscillator of sufficiently high stability to permit continuous coverage of the short-wave broadcast band without the use of crystals. The oscillator, in conjunction with suitable frequency multipliers and measuring equipment, therefore has considerable applications in the drive units of high-frequency broadcast transmitters, civil aviation transmitters, and the radio telegraph and telephone links of posts and telegraph systems.

The construction of the high-stability variable-frequency oscillator is based on the use of a Mullard precision variable capacitor in the tuned circuit. A stable inductor and its associated temperature compensating capacitors make up the rest of the frequency-determining elements.

Mullard precision capacitors were originally designed to meet the need for a variable capacitor of outstanding reliability and long-term stability for use in communications equipment : they were designed to have integral temperature compensation, good capacitance repeatability and permanence, and conformity to a straight-line frequency law. The oscillator is housed in a simple oven whose temperature is controlled to ±1 deg. Cent., which is adequate to keep frequency drift well within the prescribed limits of ±0·003 per cent. As illustrated here, the v.f. oscillators are designed for rack mounting as part of a centralised transmitter drive unit, and four can be accommodated on a standard 19in panel.



Stable Variable-Frequency Oscillator for Centralised Transmitter Drive Units

The oscillator output, which is variable between the limits 1·0 to 1·7 Mc/s, is passed through a tuned buffer amplifier to a frequency multiplier which will produce either the second (2 to 3·4 Mc/s) or the third (3 to 5·1 Mc/s) harmonic of the oscillator frequency, as required. A final wideband power amplifier delivers an output of 0·5W into 70 ohms. A low-power output on the fundamental frequency is provided for test purposes, and is taken from the buffer amplifier. The tuning condenser is provided with a slow-motion drive, which may be locked; it is used for coarse frequency adjustment, final adjustment being effected by means of a vernier inductance trimmer.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

DIAL GAUGES FOR LINEAR MEASUREMENTS

No. 907 : 1954. Price 3s. Many developments in dial gauge design have taken place since B.S. 907 was first published in 1940. The present revision takes account of this in specifying standards of performance and incorporates a number of modifications which experience of working to the previous standard has shown to be desirable. It also makes provision for back plunger dial gauges now in very general use.

In English measure two types of dial graduations are provided for : those divided into units of 0·001in (sometimes subdivided into half units of 0·0005in) and known as one-thousandth inch gauges, and those divided into units of 0·0001in and known as one-ten-thousandth inch gauges. In metric measure the standard is confined to dials graduated in units of 0·01mm. Recommended dimensions, methods of testing and notes on the care and use of dial gauges are given in appendices.

COPPER ALLOY GLOBE VALVES FOR GENERAL PURPOSES

No. 2060 : 1953. Price 4s. This is the first of a series of British Standards for copper alloy valves for general purposes. It is intended that this series will be followed by other series for ferrous valves for general engineering use.

The standard specifies requirements for rating, design and manufacture, materials, dimensions, tests and marking for copper alloy globe, angle and oblique (or "Y") valves with rising stem, inside or outside screw, with flanged or screwed ends, of Classes 100, 125, 150, 200 and 250 for a range of nominal sizes from ¼in to 3in.

Industrial and Labour Notes

Industrial Relations

On Wednesday of last week there was a debate in the House of Commons on the industrial situation. It was wound up for the Government by the Minister of Labour, Sir Walter Monckton, who said that there was, of course, room for improvement in industrial relations in this country. He did not think, however, that that improvement would be brought about by a "flash of brilliant illumination" or any form of legislation. It was now clear, Sir Walter continued, that this nation's competitive power in the markets of the world, and its survival, must depend largely upon the relationship between employers and trade unions over the whole field of British industry.

The Minister went on to refer to the negotiating machinery which had been built up over the past 100 years. Two things, he said, had developed side by side ; they were the system of collective agreements on wages and conditions of employment and the establishment of joint machinery for dealing with disputes. Sir Walter added that what he wanted to see was the further improvement, solidly attained, of that collective bargaining system. The more questions that were settled by negotiation the better for all concerned, and when, after every effort had failed to bring about peace by negotiation, then the area of dispute might yet well be narrowed and that narrowed area could be submitted to voluntary arbitration.

Sir Walter then said that he did not want to be misunderstood about arbitration. He would like to see introduced into the constitutional machinery for settling disputes—though he did not seek to impose it—some form of voluntary arbitration where it did not now exist. Where the parties, as in this country, had been brought up under a system of negotiation established over the years, there was not much validity in the argument that people would not negotiate properly if their eyes were upon arbitration at the end of the road. He (the Minister) thought that there was a sense of responsibility on both sides and a desire to settle their own affairs. Indeed, some people with experience on both sides of industry said that in the nature of things they were better placed to settle their own difficulties than any outside agency. In that case, Sir Walter commented, they would not enter into arbitration and that was all the better because it created a sense of responsibility.

Standard Costing for Small Firms

Last week-end, a conference to discuss the affairs of small firms was held at Ashorne Hill, Leamington Spa. It was organised by the British Institute of Management in co-operation with the Federation of British Industries, the National Union of Manufacturers, and the Institute of Industrial Administration.

Among the papers presented was one by Mr. H. G. Houghton, entitled "Standard Costing Over a Wide Range of Products." Mr. Houghton said that many company executives believed that a system of standard costing could not be successfully operated in a small company. He felt, however, that whether a company was large or small, concerned with mass production or jobbing engineering, the fundamental problems encountered in the efficient running of the organisation were the same. To operate efficiently, every company must have a measure of control over all aspects of expense incurred in the running of a business. The instrument by which that measure of control was achieved, Mr. Houghton suggested, should be of a predetermined and constant value and should have, as its basis, the accurate assessment of the values of the fundamental elements necessary to the efficient operation of every aspect of the business. The only instrument, Mr. Houghton said, which could progressively measure the efficiency of a company and provide the necessary information to enable management to function effectively was a system of standard costing.

Mr. Houghton subsequently dealt with the prerequisites for a standard costs system, directing attention to the need for knowledge of the capabilities of each individual machine in terms of speed, feed and class of operation that can be performed. The class of labour required and the cost of that class of labour to perform the particular operation must also be established. He went on to say that to allocate expenses of an indirect nature to the various machines, or groups of similar machines, it was necessary to establish a utilisation factor of the capacity of the plant. In general, a company must absorb the whole of its indirect expenses and overhead expenses on a percentage of its utilisation. That percentage was normally in the region of 80 per cent of the day work capacity of the plant, though there were certain machines that had as low a utilisation factor as 15 per cent of their capacity. Another observation which Mr. Houghton made was that frequently it was thought that planning was a function only necessary in a large business. That, he said, presupposed that planning was not necessary in a small organisation, especially a small organisation of a jobbing character. It was also thought that the introduction of planning in a company resulted in considerable functionalisation, which again was a matter that a small company could not afford. But, Mr. Houghton claimed, the ultimate efficient operation of a business was dependent upon the initial plan, and therefore, irrespective of the size or class of business, a company must have some predetermined values established as a framework within which it could operate.

Certification Scheme for Zinc Alloy Castings

The British Standards Institution and the Zinc Alloy Die Casters Association have drawn up a certification mark scheme for zinc alloy die castings. This means that customers can order castings guaranteed to be made under strictly controlled conditions subject to inspection by the British Standards Institution and complying with the requirements of B.S. 1004, which was published in 1942.

Wherever possible, the castings will carry the kite mark "B.S. 1004" and the die caster's name, trade mark, or B.S.I. licence number. Castings which are too small to be marked individually will be supplied in specially labelled boxes. It is stated that the new scheme is to be widely publicised both by individual licensees and by the Zinc Alloy Die Casters Association, which has sponsored it, and many firms have already had their works inspected by the British Standards Institution and have been granted licences to use the kite mark. Participation in the scheme is open to any die caster, whether or not a member of the Zinc Alloy Die Casters Association, who is willing and able to comply with the conditions. Particulars are obtainable from the British Standards Institution, 2, Park Street, London, W.1.

Iron and Steel Scrap Prices

After consultation with the Iron and Steel Board, the Minister of Supply has made an Order authorising increases in the controlled maximum delivered prices of scrap iron and scrap steel. The principal increases vary between 2s. and 4s. 1d. a ton, and have been made to allow for the recent rise in railway freight charges. The Order, which came into operation on March 8th, is entitled the Iron and Steel Scrap (Amendment No. 3) Order, 1954. It is obtainable from H.M. Stationery Office.

Price of Tin

At the beginning of this week tin prices rose to their highest level for several months. Quotations on the London Metal Exchange exceeded £700 a ton, and prices in respect of metal to be delivered in three months were given at £681 5s. a ton.

Some comments on the price of tin are made in a statement by Mr. S. H. Smith, chairman of the British Tin Investment Corporation, Ltd., which has been circulated with the annual report. Mr. Smith says that the average price of cash standard tin last year was £731 a ton, compared with £962 in 1952. During the spring and early summer of last year the cash price fell from £985 on February 9th to £568 on July 30th. Since then, Mr. Smith comments, there has been a moderate rally and, at present, price conditions are steadier. The statement goes on to explain that the primary cause of the fall in price was the knowledge that at the end of 1953 or early this year the fixed price contracts with certain countries for the purchase of tin for the U.S.A. stockpile would cease. As is so often the case, the fall was accentuated both in duration and extent by a drastic reduction in the demand for, as distinct from the consumption of, tin by the consumers, mainly those in the U.S.A. The future course of the price, Mr. Smith says, must depend in a large degree on the ultimate results of the recent tin conference convened under the auspices of the United Nations, and upon the final attitude to the draft agreement which was drawn up by that conference.

High-Purity Metals

The European Productivity Agency of the Organisation for European Economic Co-operation has stated that it is arranging a mission to the U.S.A. to study the manufacture and use of high-purity metals. The proposal is that special attention shall be given to barium, beryllium, germanium, titanium, tungsten, molybdenum, manganese, nickel, cobalt, selenium, tantalum and zirconium, as the field of application of these metals is rapidly extending, and improved production techniques are needed. It is suggested that, in Europe, the development of processes for the economic production of at least some of these metals lags far behind American practice.

The mission's investigation, it is stated, would be focused on the following aspects :—Manufacture of compounds or concentrates for the production of pure metals ; manufacture of the pure metals by various methods ; analytical processes, testing, and impurities ; and the processing of pure metals and alloys and their application. It is proposed that the United Kingdom shall be represented on this mission, although it is not yet known how many places will be available. The programme of visits will last about four weeks with a tentative starting date towards the end of June. The cost to delegates will be about £300 each. Firms or individuals interested in this mission are asked to address their inquiries to the Board of Trade (IM2 Division), Horse Guards Avenue, London, S.W.1.

Steel and Coal

Although steel production in Great Britain last month was slightly lower than in January, it was above the rate recorded in any February previously. The Iron and Steel Board has stated that the output of ingots and castings in February averaged 357,200 tons a week, which represented an annual production rate of 18,577,000 tons, compared with an annual rate of 18,325,000 tons in February last year. Pig iron production last month averaged 222,300 tons a week, and was thus at an annual rate of 11,557,000 tons, compared with 11,104,000 tons a year ago.

Coal production last week was a little lower than in the preceding week. The Ministry of Fuel and Power reports that last week's production totalled 4,579,500 tons, of which 4,389,900 tons came from the deep mines and 189,600 tons from opencast workings. In the corresponding week of last year deep-mined output amounted to 4,347,400 tons and opencast output to 227,300 tons, making a total production of 4,574,700 tons. In the first nine weeks of this year, ended March 6th, coal production totalled 41,396,100 tons, compared with 41,319,900 tons in the corresponding period of last year.

Notes and Memoranda

Air and Water

CANADIAN PACIFIC LINER.—We are informed that the passenger and cargo liner at present building at the yard of the Fairfield Shipbuilding and Engineering Company, Ltd., for Canadian Pacific Steamships, Ltd., is expected to be ready for service in the spring of 1956 and will be named "Empress of Britain."

LAUNCH OF COASTAL MINESWEEPER.—On Monday, March 8th, the coastal minesweeper H.M.S. "Dunkerton" was launched from the yard of the Goole Shipbuilding and Repairing Company, Ltd. The ship is 152ft in length by 28ft 9in beam by 14ft 9in in depth and is powered by Mirrlees diesel engines.

CARGO HANDLING.—At the last meeting of the United States committee of the International Cargo Handling Co-ordination Association, Mr. George G. Sharp was elected president. Commodore E. Brady is executive vice-president and chairman of the executive council, while Mr. Henri Kummerman, president of the MacGregor-Comerain organisation, is liaison officer to the central executive, in London.

AEROPLANE HANGAR FOR ROYAL CANADIAN MOUNTED POLICE.—An aeroplane hangar, 50ft in length and made of galvanised sheet steel was recently exported from Wolverhampton to Fort Smith in the Canadian North-West. It is to be used by the Royal Canadian Mounted Police who have just built a new airstrip at Fort Smith; the force already has eight aircraft in use. The hangar was built by the Coseley Engineering Co., Ltd.

SCOTTISH FERRIES.—William Denny and Brothers, Ltd., has completed, for service on the Kyleakin-Kyle of Lochalsh crossing between the mainland and the island of Skye, the vehicle ferry "Broadford." This vessel, which is a sister ship of the "Portree," commissioned in 1952, has a length overall of 73ft 6in by 21ft beam and a turntable measuring 32ft by 15ft 6in. Both vessels are powered by two four-cylinder Gleniffer diesel engines, each of which develops 80 b.h.p.

CABLE SHIP CONVERSION.—We are informed by Submarine Cables, Ltd., that the company has purchased the S.S. "Empire Frome" of 5360 tons deadweight for conversion into a cable ship. The ship was built in 1948 and has a length of 360ft by 51ft beam and when converted will have four cable tanks, capable of taking a total of 3750 tons of submarine cable and equivalent to about 1200 nautical miles of the lighter pattern of deep-sea cable. It is expected that the work will take about twelve months to complete, including the fitting of a Plenger activated rudder. The ship will be renamed the "Ocean Layer."

Miscellanea

INCORPORATED PLANT ENGINEERS.—The seventh annual conference of the Institution of Incorporated Plant Engineers is to be held at Scarborough from Wednesday to Friday, May 19th to 21st. The theme of the conference is "The Challenge of Modern Industry," and the opening address is to be given by Mr. H. C. I. Rogers, M.I.Mech.E., chief engineer of the Imperial Tobacco Company, Ltd.

ABRASIVE WHEEL CUTTING-OFF MACHINE.—A high-speed abrasive wheel cutting-off machine is now being made by Francis W. Birkett and Sons, Ltd., of Cleckheaton, Yorkshire. This machine is driven by a 2 h.p. motor and it will cut brass, gunmetal, phosphor bronze and steel bar up to 2in in diameter. Its maximum depth of cut is 4in and the machine has a large table, measuring 30in by 23½in.

CONFERENCE ON PRODUCTION INFORMATION.—A conference on production information arranged jointly by the Institution of Production Engineers and the A.S.L.I.B. aeronautical and engineering groups is to be held from April 2nd to 5th next, at the College of Aeronautics at Cranfield, Beds. The two main sessions of the conference will deal with "The Reporting and Dissemination of Production Information," and "The Practical Utilisation of Production Information."

BALL BEARING SLEWING RIMS.—Particulars have been received from Alexander Marcar and Co., 61, Pall Mall, London, S.W.1, of the "Roballo" bearing slewing rims made by Rothe Erde G.m.b.H., of Dortmund, Germany. These single and double race ball bearing slewing rims are made in a number of forms and are designed for fitting to the slewing motion on heavy equipment such as cranes, excavators, &c., to take the axial forces and tilting moments.

ROYAL SHOW MACHINERY ENTRIES.—The Royal Agricultural Society says that forty-seven new implement entries for silver medal awards have been received for this year's Royal Show at Windsor. From these entries, fifteen have been accepted for adjudication provided performance reports are available by the time of the Show, and six entries deferred from last year will also be included. The judges are Mr. A. Herbert Carter, Mr. Leslie Langmead and Mr. Rex Paterson.

ROYAL SOCIETY OF ARTS.—In our issue of October 16, 1953, reference was made to the bicentenary of the Royal Society of Arts, which is being celebrated this year. The celebrations begin on Monday, March 22nd at 11.30 a.m., with a commemorative service at the church of St. Martin-in-the-Fields, Trafalgar Square, London, W.C.2, at which the preacher is to be the Bishop of Peterborough. On Monday afternoon, at 3 p.m., in the Society's lecture hall at John Adam Street, Adelphi, W.C.2, congratulatory addresses will be received from kindred bodies, and an address will be given by the Earl of Radnor, K.C.V.O., chairman of the council. On Tuesday, Wednesday and Thursday, at 3 p.m., in the Society's lecture hall, the following commemorative lectures are to be delivered:—"The Arts, 1754–1954," by Dr. Nikolaus Pevsner; "Manufactures, 1754–1954," by Sir Ben Lockspeiser, F.R.S., and "Commerce, 1754–1954," by Sir Geoffrey Heyworth. On Friday evening, March 26th, there is to be a banquet at the Savoy Hotel, at which the guests of honour will be Their Royal Highnesses, the Duke and Duchess of Gloucester. On Tuesday evening, June 29th, there is to be a reception at St. James's Palace, by gracious permission of Her Majesty The Queen.

ROCK WOOL FACTORY IN SCOTLAND.—On Friday last, a new factory for the production of long fibre rock wool was opened at Stirling by the Cape Asbestos Company, Ltd., The product of the factory is to be called "Rocksil" and it will be marketed by William Kenyon and Sons, Ltd., the heat insulation engineers of Dukinfield. The raw materials for the factory will all come from Scotland—dolomite rock from Duror, and siliceous clay from Stirlingshire. At present some 10,000 cubic feet of the fibrous insulation material is being produced daily by the factory.

LIBRARY OF UNSOLVED PROBLEMS.—The Administrative Committee on Research of the American Society for Testing Materials, 1916, Race Street, Philadelphia, 3, Pa., has issued its revised bulletin entitled "Some Unsolved Problems." The problems which it reviews cover a particularly wide field in metallurgy, and it deals with difficulties relating to the manufacture, treatment, and application of many other materials. Each problem is fully stated, a synopsis of the present state of knowledge is given, together with a relevant bibliography, and finally there is a list of "questions that need to be answered." The booklet is available without charge.

FILM ON PRODUCTION IMPROVEMENT.—A film entitled "A New Approach to Production Improvement," which has been made for Philips Electrical, Ltd., was given its first showing in London last week. It depicts the work of the firm's industrial application centre, where various kinds of production equipment are demonstrated, and goes on to show the many applications of resistance and arc welding. The film also describes the application of electronic measuring instruments in industry, and deals with several different applications of high frequency heating. The running time of the film is approximately 50 minutes. Copies are available, in 16mm and 35mm sizes, for free loan to engineering societies, technical colleges and industrial undertakings on application to Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

CONFERENCE ON HYDRAULIC MECHANISMS.—The Institution of Mechanical Engineers is holding a conference on "Hydraulic Mechanisms" on Friday, March 26th, at its headquarters at 1, Birdcage Walk, London, S.W.1. At the morning session, beginning at 10.30 a.m., papers on "Hydraulic Deck Machinery," by Mr. J. R. Fairs, and "Developments in Hydraulic Transmission Drives for Ships' Cargo Winches," by Mr. M. G. R. Petty, will be discussed. In the afternoon at 2 p.m., the papers for discussion are "Aircraft Hydraulic Pumps," by Mr. E. H. Bowers; "Hydraulics as Applied to Reciprocating Machine Tools," by Mr. G. Butler, and "Hydraulic Variable-speed Rotary Drives in Industry," by Mr. F. B. Levetus. At the evening session, from 5.30 to 7.30 p.m., Mr. S. J. Wright and Mr. J. E. Bywater will present a paper on "Hydraulics in Agriculture," and Mr. T. E. Beacham will present a review entitled "Positive Displacement Machinery for Power Transmission."

PAINT SPRAY GUN.—A pressure feed internal atomising spray gun, recently introduced by B.E.N. Patents, Ltd., High Wycombe, Bucks, is designed to handle a variety of finishing materials, such as oil paints, distempers, cellulose and synthetics, as well as plastic emulsion paints. The gun works effectively with relatively low air pressures from 20 lb to 40 lb per square inch and consumes about 2 cubic feet of air per minute. A small pressure relief valve fitted in the bottom of the handle ensures that the maximum working air pressure is not exceeded. The handle and body of the gun consist of a single "Duralumin" drop forging, and it is fitted on a container with a capacity of 1 quart. The container is offset in relation to the body of the gun to improve the balance and make it easy to handle. Three spreader caps are available with the gun. One cup gives a round spray, the second a fan-shaped spray and the third a fan-shaped spray at an angle of 45 deg. This angle spray cap can be set to direct the spray upwards, downwards or sideways to facilitate the spraying of paint on floors, ceilings, or other surfaces to which access is difficult.

CANADIAN CONFERENCE ON PRESTRESSED CONCRETE.—The University of Toronto Press, Toronto, Canada, has now published a book containing the various papers presented at the Canadian Conference on Prestressed Concrete which was held in Toronto on January 28th and 29th last. About 450 delegates attended the conference and, we are informed, the papers were well received. The papers published in the book are as follows: "Why Should We Use Prestressed Concrete?" by R. F. Shaw; "Strain Gauge Tests on Prestressed Concrete Beams," by A. T. Waidelich; "An Introduction to Prestressed Concrete Theory," by H. Fealdman; "Control of Concrete Quality in Prestressed Concrete Construction," by R. B. Young and J. N. Mustard; "Steel for Prestressed Concrete," by Professor M. W. Huggins; "Significant Features of Prestressed Concrete," by Professor G. Magnel; "Statical Indeterminacy—the Foundation of Prestressed Concrete Design," by Dr. T. O. Lazarides; "Report on Prestressed Concrete Research," by A. L. Parme; and "The World's Largest Prestressed Concrete Spans," (a description of the three arch bridges recently built in Venezuela), by R. Shama.

MANAGERS IN INDUSTRY.—The Cambridge University Board of Extra-mural Studies is arranging a residential course for managers in industry. It is to be held at Madingley Hall, Cambridge, from June 28th to July 23rd. The course is designed to throw light on the role of the manager and on his personal responsibility in present-day society. In the lectures to be given it is intended to examine the opportunities and responsibilities arising from the manager's relationships with members of his own organisation, with institutions such as trade unions, with the State, and with the community as a whole. Admissions to the course are limited to twenty-four, the age range being from twenty-eight to thirty-five. The fee, including tuition, board residence and gratuities, is £80, and full details may be obtained from the Secretary, Course for Managers in Industry, Stuart House, Cambridge.

Personal and Business

MR. C. A. EDWARDS has been appointed sales manager of Bryce Berger, Ltd., Staines, Middlesex.

A. V. ROE AND CO., Ltd., announces the appointment of Mr. R. J. Falk as superintendent of flying.

MR. S. S. SEABROOK has been appointed publicity manager of the Dowty group of companies, Cheltenham.

THE EARL OF SCARBOROUGH, K.G., has consented to become Patron of the Midland Institute of Mining Engineers.

HOOVER, Ltd., Perivale, Middlesex, announces the appointment of Mr. K. M. Jones as education and training officer.

MR. C. P. D. FRANKLIN and Mr. W. Whittington have been appointed directors of the main board of British Ropes, Ltd.

SLOUGH METALS, Ltd., Trading Estate, Slough, announces the appointment of Mr. L. Gamsa as foundry sales manager.

MR. HARRY ARKLE, general freight traffic manager of the Canadian Pacific Railway, has been appointed European general manager for the company.

W. T. HENLEY'S TELEGRAPH WORKS COMPANY, Ltd., states that Mr. H. D. Parsons has been appointed general sales manager. Mr. P. H. Scrine has been appointed assistant manager for India.

JAGUAR CARS, Ltd., Coventry, states that it has formed a wholly owned American subsidiary company entitled Jaguar Cars North American Corporation. Its address is 487, Park Avenue, New York.

THE DE HAVILLAND ENGINE COMPANY, Ltd., will move its registered office and administrative headquarters, on March 15th, to Leavesden Airfield, Leavesden, Herts (telephone, Garston 2261; telegrams, "Gipsy, Watford.").

MR. W. H. LAWRENCE is retiring from the Fry group of companies on March 31st. He joined the Eyre Smelting Company, Ltd., in 1919, and was elected a director in 1931, and has also served on the board of Fry's Metal Foundries, Ltd., since 1934.

THE PRESIDENT OF THE BOARD OF TRADE has appointed Mr. H. Douglass, general secretary of the Iron and Steel Trades Confederation, a member of the committee to advise and make recommendations about future policy as to the taking of censuses of production and distribution.

AUTOMOTIVE PRODUCTS COMPANY, LTD., AND ASSOCIATED COMPANIES announce that Messrs. A. C. Burdon, N. C. A. Spurgeon, and E. W. Swales have been appointed deputy managing directors and that Messrs. E. Beaumont, S. M. Parker and S. Westwood Smye have been made executive directors.

THE TELEGRAPH CONSTRUCTION AND MAINTENANCE COMPANY, Ltd., Telcon Works, Greenwich, S.E.10, announces the appointment of Mr. C. L. G. Fairfield, M.I.E.E., as general sales manager covering cables, plastics and engineering products. Mr. E. H. Gosling has been appointed home sales manager for these products.

MR. A. A. PAGET.—In reporting in our issue of February 26th that Mr. Paget has been appointed works manager of Vandome and Hart, Ltd., we referred to him as chief planning engineer of W. and T. Avery, Ltd. This was an error; Mr. Paget held the appointment of planning engineer of a branch factory at Sherburn-in-Elmet. Our apologies are due to the authentic chief planning engineer of the Avery organisation.

MASSEY-HARRIS-FERGUSON, Ltd., has announced some details of its eastern hemisphere organisation. An executive committee, with Mr. J. S. Duncan as chairman, supervises the four main subsidiary companies which have their headquarters in the United Kingdom, namely, Massey-Harris-Ferguson (Engineering), Ltd., Massey-Harris-Ferguson (Sales), Ltd., Massey-Harris-Ferguson (Export), Ltd., and Massey-Harris-Ferguson (Manufacturing), Ltd. Mr. Harry Ferguson, chairman of the parent company, is also chairman of Massey-Harris-Ferguson (Engineering), Ltd., and Mr. J. M. Chambers, the chief engineer, has been appointed a director.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, states that Dr. C. Dannatt, M.I.E.E., has been appointed deputy managing director. He has been assistant managing director since August, 1951. Mr. A. C. Main, M.I.E.E., director and works manager at the Trafford Park works, has been appointed director of manufacture, and Mr. E. W. Steele, M.I.Mech.E., formerly director and general manager of works, has retired from executive duties, but remains a director. Mr. J. F. Perry, managing director of Metropolitan-Vickers Electrical Export Company, Ltd., has been appointed a director of the parent company.

British Patent Specifications

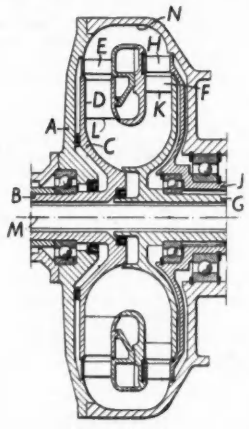
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of the specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

HYDRAULIC MACHINERY

703,517. May 25, 1948.—HYDRAULIC TORQUE CONVERTERS, Svenska Rotor Maskiner Aktiebolag, of Nacka, Sweden (formerly Aktiebolaget Ljungströms Angturbin, of 32, Kungsgatan, Stockholm 15, Sweden), and Frank Watson, of Aldwych House, Aldwych, London, W.C.2.

As shown in the drawing the torque converter includes a stationary casing *A* surrounding the rotating member of the converter and comprising an input shaft *B* carrying an impeller or pump wheel *C* provided with impeller blades *D*. Disposed beyond



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the impeller blades in the hydraulic circuit in the direction of flow of liquid through it, there follows a first ring of turbine blades *E* which, together with a last turbine blade ring *F*, are fixed to a turbine disc integral with an output shaft *G*. Between the turbine stages *E* and *F* is inserted a reaction or guide blade ring *H* carried by a disc mounted on a hollow shaft *J* which is connected to the turbine shaft through a reversing gear (not shown) or locked to the stationary casing. As will be clear from the drawing, the outlet *K* of the last turbine blade ring *F* discharges fluid direct to the inlet *L* of the pump blade ring. According to the invention, the outlet *K* of the turbine blade ring *F* is so disposed relatively to the axis of rotation *M* that the ratio between the radius from the axis to the outlet *K* and the radius from axis *M* to the outer edge *N* of the converter working chamber lies within the limits of 0·5 and 0·65. It is pointed out that there is a particular advantage in a torque converter of the kind described having the specified ratio between 0·5 and 0·65. Tests have shown that if the ratio of the torque at start to the torque at shifting point is set out against varying ratios of the radii referred to a curve is obtained which is somewhat flat up to the point 0·5 and then ascends in a steeply rising form. Below 0·5 the efficiency is some 4 to 5 per cent less and above 0·65 there is also a reduced efficiency because the shift point takes place at too low a speed, and the efficiency curve is somewhat discontinuous due to cavitation which it would appear impossible to avoid in the range above 0·65. The invention is equally applicable to other forms of converters, such as those having a rotating casing.—*February* 3, 1954.

METALLURGY

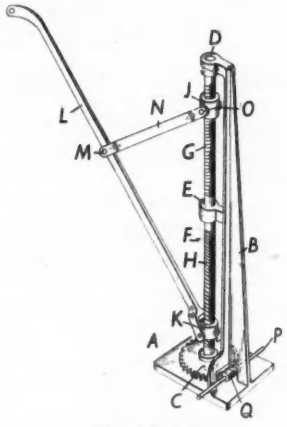
703,142. June 18, 1952.—CONTINUOUS REGENERATION OF WASTE PICKLING LIQUORS, Othmar Ruthner, 12, Salmgasse, Vienna III, Austria.

The invention is a process for continuously regenerating spent pickling liquors with simultaneous extraction of iron oxide and recovery of the acid. By the process, out of a sulphuric acid waste pickling liquor, the hydrated ferrous sulphates are precipitated, separated and after suitable preliminary drying, converted into hydrates with low water content. Treatment of these hydrated ferrous sulphates with hydrogen chloride produces in addition to sulphuric acid, crystalline ferrous chloride. The ferrous chloride is then purified by recrystallisation and after suitable granulation, transferred to a reaction furnace. In this furnace the ferrous chloride is decomposed by steam at a temperature of 450 deg. Cent. to iron oxide and hydrogen chloride. The hot hydrogen chloride is conducted in counterflow for the purpose of heat exchange through the steam and thereupon treated in a washing tower with concentrated sulphuric acid. The dry, gaseous hydrogen chloride is then returned for renewed production of ferrous chloride while the aqueous sulphuric acid is freed from water in a concentrating plant. The water leaves the concentrating plant in the form of steam and passes through the heat exchangers back to the reaction furnace.—*January* 27, 1954.

CRANES AND LIFTING APPLIANCES

703,536. August 29, 1952.—CRANES, Robert Stephen Babare, 3817, No. 35th Street, Tacoma, Washington, U.S.A., and George Martin Babare, 2212, W. Day Island Boulevard, Tacoma, Washington, U.S.A.

The invention relates to improvements in cranes, particularly designed for logging purposes. In the drawing *A* is a base, and rising from it is a standard *B*. A bearing *C* is formed in the base, and in the top of the standard is a bearing *D*, and extending from the standard and in alignment with the bearings *D* and *C*



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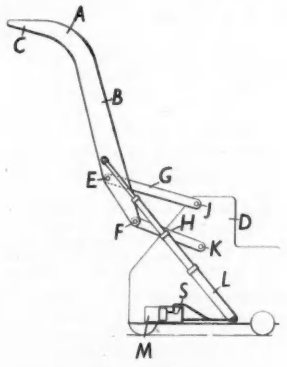
is an intermediate bearing *E*. Mounted in the bearings is a vertical shaft *F* having right and left-hand threads *G* and *H*. A nut *J* is mounted on the upper threads and a nut *K* is mounted on the lower threads. Pivoted to the lower nut *K* is a boom *L*, and pivoted to the boom at *M* is a brace *N* pivoted to the upper nut *J*. Secured to the lower end of the shaft is a worm gear and meshing with this gear is a worm mounted on a shaft *P* on the base. The power shaft is controlled by suitable reversing mechanism to regulate the movement of the shaft. In operation the shaft is operated, and through the medium of the gears the screw shaft is rotated, and the boom is elevated. When the boom is in position carrying a log, and it is desired to swing the load around to deliver it, the boom can be readily manually rotated. To lower the boom the power shaft is operated to rotate the screw shaft in the opposite direction.—*February* 3, 1954.

703,554. December 14, 1950.—CRANES, Edward Arthur Thorp and Reginald Waghorn Brian Harvey, both of 44, Saint John's Road, Tunbridge Wells, Kent.

As shown by the drawing, the jib is cranked at *A* to form the main upright *B*, and a forward extension *C*. The jib is mounted on a mobile carriage *D* arranged for self-propulsion. The jib is mounted at its lower end on two pivots *E* and *F*, which are pivoted



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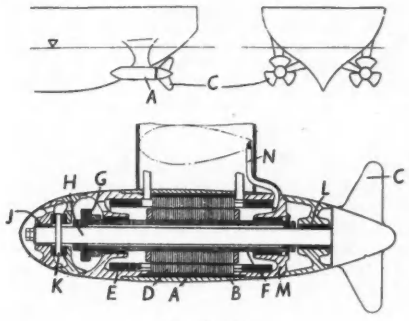
ends of independent links *G* and *H* respectively. The links are themselves pivoted to the carriage at *J* and *K*. It will be seen that the upper link *G* is rather longer than the lower link *H*, and that they are approximately parallel when the jib is raised to its highest position. The distance between the pivots *J* and *K* is slightly less than the distance between the pivots *E* and *F*. The drawing shows a hydraulic drive and in this example both links *G* and *H* are idle tie-rods serving to guide the jib in its correct path. A hydraulic ram *L* pivoted at its base serves to operate the jib. The large diameter of the ram is effective at the commencement of the lift and the smaller diameters come into operation at the upper end of the lift. The rate of movement of the ram thus increases progressively if the input of oil is constant in volume. This has the effect of keeping the rate of movement of the point of the jib substantially constant. The hydraulic prime mover is shown diagrammatically at *M*, from which oil is delivered via pipelines, through a non-return valve to the ram.—*February* 3, 1954.

MARINE ENGINEERING

703,777. May 10, 1951.—DRIVING MECHANISM FOR SHIPS, Pleuger K.G., Hamburg-Wandsbek, Friedrich-Ebertdamm 101A, Germany.

A streamlined casing *A* on each side of the stern of a ship encloses a motor *B* which drives the propeller *C*. As shown in the lower view, the electric motor is a three-phase a.c. motor, the stator lamina-



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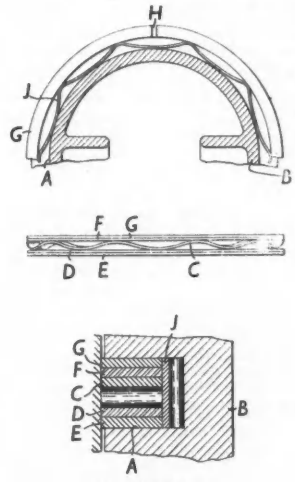
tions *D* of which are enclosed by the tubular casing and comprise the windings *E*, which are provided with waterproof insulations. The rotor of the motor has a squirrel-cage and is fastened to a hollow shaft *F*. At both its ends this shaft is supported by journal bearings. The front or bow end of the hollow shaft *F* carries a disc *G* of a shock-absorbing coupling which is fastened to a shaft *H* within the hollow shaft. At its front end shaft *H* is supported by a journal bearing *J*. At the coupling side the shaft carries the thrust bearing plate *K* which is supported at both sides by thrust collars. The rear end of shaft *H* is supported in a journal bearing *L*, the case of which is fastened to the bearing case *M*. The hub of a propeller *C* is secured to the rear end of shaft *H*. The waterproof insulated windings *E* of the stator laminations *D* are connected to a three-phase a.c. generator by means of a cable *N*. The generator may be arranged at any place in the body of the ship.—*February* 10, 1954.

INTERNAL COMBUSTION ENGINES

703,282.—April 12, 1951.—PISTON-RING ANNULAR SEAL ARRANGEMENTS, Wellworthy Piston Rings, Ltd., John William Howlett and Arthur John Woolcott, all of Radial Works, Standford Road, Lymington, Hampshire.

The invention relates to sealing between a piston and a co-operative cylinder, and is an addition to the invention described in Specification No. 617,700.



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As will be seen from the drawings, a groove *A* of substantially rectangular cross section is provided peripherally in the piston wall *B*. The ring member *C*

comprises a strip of wavy spring metal formed into annular shape. This ring is assembled into a sandwich within the groove with a pair of split steel rings *D* and *E*, on one radial face of the ring *C*, and a pair of split rings *F* and *G* on the opposite face of the ring. Ring *F* is formed from bronze alloy. The split in the rings is shown at *H*. To bias the sandwich in the radial direction to effect sealing of the piston against the cylinder wall, there is provided a further strip *J* of wavy metal whose corrugations are arranged transversely of those of the strip *C* between the split ring members. This radially compressible strip *J* is arranged to bottom in the groove *A* in the piston wall, exerting pressure to cause the assembly to bear against a cylinder wall as shown.

In the design shown, the bronze ring is placed immediately next the axially compressible and expansible ring, assuming a vertical mounting of the piston and cylinder in which it reciprocates crown uppermost. —*February* 3, 1954.

Contracts

VICKERS-ARMSTRONGS, Ltd., announces that an order has been received from Canadian Pacific Steamships, Ltd., to build a 22,500-ton passenger and cargo liner for the company's Britain to Canada service. The ship, which will be built at Vickers-Armstrong's Naval Yard, Walker, will have a length between perpendiculars of 600ft, a breadth moulded of 85ft, a depth moulded of 48ft, a draught of 29ft, and a service speed of 21 knots. A total of 150 first-class and 900 tourist-class passengers will be carried and the ship will have Denny-Brown stabilisers and will be propelled by double reduction geared turbines of 3000 s.h.p., constructed by the shipbuilders at the Barrow works. The value of the contract is stated to be 15,000,000 dollars.

THE ENGLISH ELECTRIC COMPANY OF CANADA, Ltd., has received an order for four water turbines, having what is believed to be the largest individual electric power output of any turbines of their kind. They are designed to develop a rated output of 150,000 b.h.p. at 277 r.p.m. under a net head of 785ft. Each machine will be capable of developing 175,000 b.h.p. under a maximum net head of 875ft. The turbines are for the Commission's Lac Casse (Bersimis) development on the north shore of the St. Lawrence River, some 70 miles north of Forestville down river from Quebec. The Bersimis River will be dammed and the water will flow from an artificial lake some 9 miles through a tunnel to an underground power plant. The basic development and engineering are being done by the Hydraulic Department of The English Electric Company, Ltd., in England, while the actual manufacture will be carried out in the Group's John Inglis plant at Toronto.

METROPOLITAN-VICKERS ELECTRICAL EXPORT COMPANY, LTD., has also received an order for four vertical shaft water wheel generators (120MVA normal and 138MVA maximum continuous rating, 60 c/s) for the Lac Casse power station on the Bersimis River.

THE MARCONI INTERNATIONAL MARINE COMMUNICATION COMPANY, Ltd., has received an order from the Tees Conservancy Commissioners for the extension of the present v.h.f. communication scheme to include a further five vessels. The present system, started in 1949, consists of three Marconi Marine "Seaphone" transmitter/receivers, one fitted ashore for use as a headquarters set for passing instructions and orders, and the others on board the pilot vessel "B. O. Davies" and the H.M. Customs tender "Argus." The new order involves the installation of "Seaphones" on board the tugs "Joanetta" and "John H. Amos," the self-propelled hoppers "T. C. C. Hopper No. 5" and "T. C. C. Hopper No. 6," and the motor launch "Tees Harbour Master." In addition, ancillary equipment is to be provided for the tugs "C. J. Archer" and "Sir Hugh Bell," so that "Seaphones" may be transferred from other vessels for use on these two when desired. In this way eight transmitter/receivers will provide a v.h.f. communication service between the shore and any seven of nine vessels to facilitate the speedy transfer of information and orders concerning the arrival and departure of ships, berthing arrangements and dredging and river maintenance operations necessary in the Tees area.

CONTRACTS have been placed by the British Electricity Authority during the past month for power stations, transforming stations and transmission lines amounting in the aggregate to £8,342,748. The principal contracts include Brighton "B" power station, foundations for two turbo-generator sets (John Morgan (London), Ltd.); Portishead "B" power station, near Bristol, superstructure (John Laing and Son, Ltd.); South Denes power station, Yarmouth, structural steelwork (Dawnays, Ltd.), and two 72MVA generator transformers (British Thomson-Houston Company, Ltd.); Willington "A" power station, near Derby, main civil engineering works (Marples Ridgway and Partners, Ltd.), and structural steelwork (Edward Wood and Co., Ltd.); Hams Hall "C" power station, near Birmingham, three 72MVA, 141·6/11·8kV generator transformers (General Electric Company, Ltd.); Ocker Hill power station, Tipton, Staffs, structural steelwork (Horseley Bridge and Thomas Piggott, Ltd.); Connah's Quay power station, near Flint, structural steelwork (Francis Morton and Co., Ltd.); Huddersfield power station, reinforced concrete cooling tower (Davenport Engineering Company); Stella South power station, near Newcastle upon Tyne, auxiliary cables and accessories (Pirelli-General Cable Works, Ltd.); Fleetwood power station, one 300,000 lb per hour boiler (Richardsons, Westgarth (Hartlepool), Ltd.); Portobello power station, Edinburgh, boiler feed pumps (G. and J. Weir, Ltd.); Melksham substation, Wilts, 275kV, 7500MVA and 132kV, 3500MVA switchgear (Metropolitan-Vickers Electrical Company, Ltd.); Connah's Quay substation, near Flint, 132kV overhead line (British Insulated Callender's Construction Company, Ltd.); Carrington substation, near Manchester, 275kV, 7500MVA switchgear (Metropolitan-Vickers Electrical Company, Ltd.); Three Bridges-Leigh, 132kV overhead line (British Insulated Callender's Construction Company, Ltd.); Bedford-Goldington-Little Barford, 132kV overhead line work (Watsham's, Ltd.); and Monk Fryston-Rochdale, 275kV overhead line (Balfour Beatty and Co., Ltd.).

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases, the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

To-day, March 12th.—SCOTTISH SECTION: The University, Edinburgh, "The Acoustic Design and Measurement of Buildings," H. C. Watson, 7 p.m.

Tues., March 23rd.—W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, "Industrial Application of Electronic Instruments," A. G. Wray, 7.15 p.m.

DIESEL ENGINE USERS ASSOCIATION

Thurs., March 18th.—Caxton Hall, Westminster, London, S.W.1, "Preventive Maintenance from Breakdown Experience," H. D. Adam, 2.30 p.m.

INCORPORATED PLANT ENGINEERS

To-day, March 12th.—BIRMINGHAM BRANCH: Imperial Hotel, Birmingham, Contractors' Plant Discussion Group, 7.30 p.m.

Mon., March 15th.—MERSEYSIDE AND N. WALES BRANCH: Radiant House, Bold Street, Liverpool, Annual General Meeting, 7.15 p.m.

Tues., March 16th.—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, Annual General Meeting, 7.15 p.m.——S. WALES BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, "Modern Hand Tools and Mechanical Aids," 7.15 p.m.

Wed., March 17th.—KENT BRANCH: Bull Hotel, Rochester, "Metal Spraying," 7 p.m.——WESTERN BRANCH: Grand Hotel, Bristol, Annual General Meeting, "Steam Flow Measurement and its Relation to Thermal Efficiency," W. M. Barber, 7.15 p.m.

Thurs., March 18th.—PETERBOROUGH BRANCH: Eastern Gas Board's Demonstration Theatre, Church Street, Peterborough, Annual General Meeting, "Any Questions," 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Thurs., March 18th.—W. MIDLANDS SECTION: Imperial Hotel, Birmingham, "Heat Exchangers," H. E. Upton, 7 p.m.——KINGSTON UPON HULL AND E. MIDLANDS SECTION: Metropole Hotel, King Street, Leeds, Films, "Oil in Industry," introduced by T. M. Green, 7.30 p.m.

Fri., March 19th.—EDUCATION GROUP: 85, Minories, London, E.C.3, Annual General Meeting, Discussion on "The Part the University Has to Play in the Training of the Marine Engineer," opened by A. W. Jones, 5.30 p.m.

INSTITUTE OF METALS

Mon., March 15th.—SHEFFIELD LOCAL SECTION: Mappin Hall, St. George's Square, Sheffield, "Some Factors Affecting Spring Design," W. R. Berry, 7.30 p.m.

Tues., March 16th.—S. WALES LOCAL SECTION: Metallurgy Department, University College, Singleton Park, Swansea, Annual General Meeting, 6.45 p.m.

INSTITUTE OF PETROLEUM

Wed., March 17th.—STANLOW BRANCH: Grosvenor Hotel, Chester, "Refinery Operational Programming," A. N. Holmes, 7.30 p.m.

Fri., March 19th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, Symposium on "Metal-Working Oils," C. B. Davies, 2.15 and 5 p.m.

INSTITUTE OF REFRIGERATION

Tues., March 16th.—Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, Discussion on "The Control of Relative Humidity in Cold Stores," opening speakers M. E. Anderson and G. Mann, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Wed., March 17th.—N.W. CENTRE: Victoria Hotel, Wigan, "Carburation," L. J. Spencer, 7.30 p.m.

Thurs., March 18th.—YORKSHIRE CENTRE: Hotel Metropole, King Street, Leeds, 1, "Gas and Electric Arc Welding to the Construction and Maintenance of Road Transport Vehicles," G. G. Musted, 7.30 p.m.——LONDON CENTRE: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, "Thin Wall Bearings," P. Holligan, 6.30 p.m.

INSTITUTE OF TRANSPORT

Mon., March 15th.—METROPOLITAN SECTION: 80, Portland Place, London, W.1, Symposium on "Catering in Relation to Transport," G. K. Portman-Dixon and W. P. Keith, 5.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., March 16th.—ORDINARY MEETING: Great George Street, Westminster, London, S.W.1, "Woodhead New Tunnel: Construction of a Three-Mile Main Double-Line Railway Tunnel," P. A. Scott and J. I. Campbell, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., March 16th.—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, "The Minimum-Moment-of-Error-Squared Criterion: A New Performance Criterion for Servo Mechanisms," J. H. Westcott; "The Behaviour of a Remote Position Control Servo Mechanism with Hard-Spring Non-Linear Characteristics," J. C. West and P. N. Nikiforuk, 5.30 p.m.——S.E. SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, "Some Aspects of the Design of U.H.F. Mobile Radio Systems," E. P. Fairbairn, 7 p.m.——N. MIDLAND CENTRE: British Electricity Authority, 1, Whitehall Road, Leeds, 1, "Utilisation of Electric Power in Oilfields," G. F. Shields and H. Myers; "Aspects of Induction Motor Drives and Methods of Control," 6.30 p.m.

Thurs., March 18th.—UTILISATION SECTION: Savoy Place, London, W.C.2, Discussion on "The Training and Responsibilities of Marine Electrical Engineers," opened by G. O. Watson, 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Wed., March 17th.—DUNDEE BRANCH: Royal British Hotel, Dundee, "Aims and Objects of the National Physical Laboratory," C. F. Watkinson, 7.30 p.m.

Thurs., March 18th.—N.W. BRANCH: Engineers' Club, Albert Square, Manchester, "The Testing of Screw Threads," A. Whitehead, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., March 16th.—JOINT MEETING WITH GREENOCK ASSOCIATION OF ENGINEERS AND SHIPBUILDERS: The Lorne, Greenock, "Modern Developments in the Design and Manufacture of Welded Pressure Vessels," M. B. Hamilton and J. McIntyre, 7.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., March 17th.—Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, Annual General Meeting, "Experiences with British Railway Standard Locomotives," E. S. Cox, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, March 12th.—GROUP DISCUSSION: 1, Birdcage Walk, Westminster, London, S.W.1, Industrial Administration and Engineering Production Group, "The Productivity Report on Design for Production," 5.30 p.m.

Mon., March 15th.—MIDLAND BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting and Chairman's Address, 7 p.m.

Tues., March 16th.—SCOTTISH BRANCH: Room 24, Royal Technical College, Glasgow, Annual General Meeting, "Difficulties met with in the Manufacture of Doxford Engines," J. K. Roscamp, 7.30 p.m.

Fri., March 19th.—ANNUAL GENERAL MEETING: 1, Birdcage Walk, London, S.W.1, Corporate and Non-Corporate Members only, 5.30 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., March 18th.—Geological Society, Burlington House, Piccadilly, London, W.1, Discussion of "Some Grinding Tests with Spheres and Other Shapes," G. Chad Norris; and "A Method of Predicting the Performance of Commercial Mills in the Fine Grinding of Brittle Materials," G. Lowrie Fairs, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, March 12th.—EASTERN COUNTIES SECTION: Diocesan Hall, Tower Street, Ipswich, Annual General Meeting, "A Machine Tool Symposium," 6.30 p.m.

Mon., March 15th.—DERBY SECTION: College of Art, Green Lane, Derby, Annual General Meeting, followed by Films, 7 p.m.——N.E. SECTION: North of England Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle upon Tyne, "Problems Involved in the Manufacture of Mineral Insulated Metal-Covered Cables," J. E. I. Gaymer, 7 p.m.

Tues., March 16th.—OXFORD SECTION: Town Hall, Oxford, Annual General Meeting, followed by a Film Show, 7.15 p.m.

Wed., March 17th.—BIRMINGHAM SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, 3, "The Manufacture and Development of Jig Boring Machinery," W. H. Jaye, 7 p.m.——CORNWALL SECTION: Camborne School of Mines, Camborne, Cornwall, "Some Applications of Rubber in Engineering," G. W. Trobridge, 7.15 p.m.——EDINBURGH SECTION: North British Station Hotel, Edinburgh, "A History of Brewing, with Comments on Production," R. Allan, 7.30 p.m.——HALIFAX SECTION: George Hotel, Huddersfield, "Designing a Cast Iron Designer," K. H. Collinson; "Radial Drill Time-Saving Devices," T. P. N. Burness, 7.15 p.m.

Thurs., March 18th.—GLASGOW CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Noise and Vibration in Machinery," A. J. King, 7.30 p.m.——SOUTHERN SECTION: Polygon Hotel, Southampton, "Production Problems on the Javelin," W. W. W. Downing, 7 p.m.

IRON AND STEEL INSTITUTE

Thurs., March 18th.—IRON AND STEEL ENGINEERS' GROUP: 4, Grosvenor Gardens, London, S.W.1, "Treatment of Water for the Iron and Steel Industry," A. J. Lamb and A. H. Waddington, 10.30 a.m. to 12.45 p.m.; Buffet Luncheon, 12.45 p.m. to 2 p.m.; "Modern Industrial Boiler Plant," W. P. C. Ungoed, 2 p.m. to 4 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, March 12th.—ORDINARY MEETING: Townsend House, Greycoat Place, London, S.W.1, "General Principles of Boiler Water Treatment," W. F. Gerrard, 7 p.m.

Mon., March 15th.—SHEFFIELD AND DISTRICT SECTION: Royal Victoria Hotel, Sheffield, "Developments and Future Possibilities in Electricity Generation," Sir John Hacking, 7.30 p.m.

Fri., March 19th.—INFORMAL MEETING: Townsend House, Greycoat Place, London, S.W.1, "A Review of Plastics Piping," B. T. A. Holland, followed by a Film, "The Story of Tenite," 7 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, March 12th.—Mining Institute, Newcastle upon Tyne, "Marine Shafting Alignment," G. Yellowley and J. E. Richards, 6.15 p.m.

OLD CENTRALIANS

Mon., March 15th.—Chez Auguste Restaurant, 47, Frith Street, London, W.1, "Some Engines which Save Fuel," Sir Harold Roxbee Cox, 12.45 p.m.

REINFORCED CONCRETE ASSOCIATION

Wed., March 17th.—11, Upper Belgrave Street, London, S.W.1, "Recent Research on Deformed Reinforcing Bars," K. Hajnal-Konyi, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., March 16th.—4, Hamilton Place, London, W.1, "The Development of the Spill Flow Burner and its Control System for Gas Turbine Engines," F. H. Carey, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., March 15th.—Institution of Civil Engineers, Great George Street, London, S.W.1, "The Landlord and Tenant Bill," Right Honourable Sir David Maxwell Fyfe, 5.50 p.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., March 15th.—The University Building, St. George's Square, Sheffield, "Some Factors Affecting Spring Design," W. R. Berry, 7.30 p.m.

WOMEN'S ENGINEERING SOCIETY

Wed., March 17th.—LONDON BRANCH: 35, Grosvenor Place S.W.1, "Industrial Television," 7 p.m.